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Preliminary Data Summary for the Hospitals Point Source Category

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This document is one of a series of Preliminary Data Summaries prepared by the Office of Water Regulations and Standards of the U. S. Environmental Protection Agency. The Summaries contain engineering, economic and environmental data that pertain to whether industrial facilities in various industries discharge pollutants in their wastewaters and whether the EPA should pursue regulations to control such discharges. The summaries were prepared in order to allow EPA to respond to the mandate of Section 304(m) of the Clean Water Act, which requires the Agency to develop plans to regulate industrial categories that contribute to pollution of the Nation's surface waters. Summaries for categories already subject to rulemaking were developed for comparison purposes, and contain only the minimum amount of data needed to provide some perspective on the relative magnitude of the pollution problems created across the categories.

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Preliminary Data Summary for the Hospitals Point Source Category

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PRELIMINARY DATA SUMMARY
FOR THE
HOSPITALS
POINT SOURCE CATEGORY

Office of Water Regulations and Standards
Office of Water
United States Environmental Protection Agency
Washington, D.C.

August 1989

PREFACE

This is one of a series of Preliminary Data Summaries prepared by the Office of Water Regulations and Standards of the U.S. Environmental Protection Agency. The Summaries contain engineering, economic and environmental data that pertain to question as to whether the industrial facilities in various industries discharge pollutants in their wastewaters and whether the EPA should pursue regulations to control such discharges. The summaries were prepared in order to allow EPA to respond to the mandate of section 304(m) of the Clean Water Act, which requires the Agency to develop plans to regulate industrial categories that contribute to pollution of the Nation's surface waters.

The Summaries vary in terms of the amount and nature of the data presented. This variation reflects several factors, including the overall size of the category (number of dischargers), the amount of sampling and analytical work performed by EPA in developing the Summary, the amount of relevant secondary data that exists for the various categories, whether the industry had been the subject of previous studies (by EPA or other parties), and whether or not the Agency was already committed to a regulation for the industry. With respect to the last factor, the pattern is for categories that are already the subject of regulatory activity (e.g., Pesticides, Pulp and Paper) to have relatively short Summaries. This is because the Summaries are intended primarily to assist EPA management in designating industry categories for rulemaking. Summaries for categories already subject to rulemaking were developed for comparison purposes, and contain only the minimal amount of data needed to provide some perspective on the relative magnitude of the pollution problems created across the categories.

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EXECUTIVE SUMMARY

The Industrial Technology Division (ITD) of the U.S. Environmental Protection Agency conducted a study of the Hospitals Category as a result of findings from the Domestic Sewage Study (DSS). The purposes of the study were to obtain technical information for use in determining if additional effluent limitations guidelines and standards pursuant to the Clean Water Act (CWA) need to be promulgated for this category and to provide a source of current information about priority and hazardous pollutant discharges from this category for permit writers and publicly owned treatment works (POTWs).

This study involved only a technical support study. No environmental or economic impact analyses were performed as part of this effort. The technical support study consisted of two parts: the collection and analysis wastewater samples from representative hospitals and the collection of sufficient information about the industry to develop an updated industry profile. The sampling program, conducted at four hospitals, helped characterize the industry's wastewater with respect to the 126 priority pollutants as well as the 250 additional compounds on ITD's List of Analytes. The Hospital Industry had never been sampled for either group of pollutants or compounds.

The results of the sampling program are summarized in the table on the next page which presents the Agency's estimates for various types of pollutant discharges to air, water, and sludge by the Hospital category. The information used to develop an updated industry profile of the Hospital category is presented mainly in section 2.0 of this document.

ESTIMATED AMOUNTS OF POLLUTANTS DISCHARGED TO WATER, AIR AND CAPTURED IN SLUDGE

	Estimated Waste Discharges (Units are lbs/yr) To POTWs and EOP Treatment	To Recieving Waters	Air	Sludge
BOD_5	259,000,000	a	NA	NA
TSS	135,000,000	a	NA	a
COD	567,000,000	a	NA	NA
Priority Pollutants				
Volatiles	37,960	3,037	33,405	--
Metals	255,135	a	--	b
Semivolatiles	56,210	a	--	--
Nonpriority Pollutants				
Volatiles	545,675	43,654	480,194	--
Metals	314,995	a	--	b

NA - Not applicable

a - Insufficient data are available for a reliable estimate

b - A significant amount of metals will apportion to sludge

cont from BDS

SECTION 1.0

INTRODUCTION

1.1 SUMMARY

This document summarizes the most current information available regarding the discharge of wastewater and solid wastes containing priority and hazardous non-priority pollutants by hospitals. The objectives of this document are to (1) provide a technical basis for determining whether additional national regulations should be developed pursuant to the Clean Water Act (CWA), and (2) make available preliminary information regarding the discharge of priority and hazardous non-priority pollutants by the hospital industry.

The hospital industry profile is presented in Section 2.0. Section 3.0 characterizes hospital wastewater in terms of the presence of priority and hazardous non-priority pollutants and provides additional information on these and other pollutant discharges from hospitals. Various waste management practices and control and treatment technologies are described in Section 4.0. Environmental and economic impact analyses have not been performed as part of this study and, consequently no such analyses are discussed in this document.

1.2 PURPOSE AND AUTHORITY

The U.S. Environmental Protection Agency (EPA) is required by Section 301(d) of the Federal Water Pollution Control Act Amendments of 1972 and 1977 (the CWA) to review and revise, if necessary, effluent limitations promulgated pursuant to Sections 301, 304, and 306, within five years of promulgation of these regulations. In conjunction with this review program and as a result of a court settlement with several environmental groups, EPA has undertaken a major examination of toxic pollutants discharged by industrial sources.

To achieve these goals, the Industrial Technology Division (ITD) is responsible for (1) developing, proposing, and promulgating effluent limitations guidelines, new source performance standards (NSPS), pretreatment standards, and best management practices (BMPs) for industrial point source discharges; (2) assuring the adequacy and validity of scientific, economic, and technical data and findings used to support the effluent limitations and standards; (3) gathering, developing, and analyzing data and background information basic to the annual review and periodic revision of the limitations and standards; and (4) developing technical information required for the judicial review of effluent limitations guidelines and standards.

In addition to its responsibilities under the CWA, EPA is also charged by the Resource Conservation and Recovery Act of 1976 (RCRA) with oversight of "cradle-to-grave" management of hazardous solid wastes. Section 3018(a) of RCRA, as amended by the 1984 Hazardous and Solid Waste Amendments (HSWA), directed EPA to submit a report to Congress concerning wastes discharged through sewer systems to publicly owned treatment works (POTWs) that are exempt from RCRA regulation as a result of the Domestic Sewage Exclusion (DSE) of RCRA. The DSE, established by Congress in Section 1004(27) of RCRA, provides that solid or dissolved material in domestic sewage is not solid waste as defined in RCRA; therefore, it cannot be considered hazardous waste for RCRA purposes. The DSE applies to domestic sewage and industrial wastes discharged to POTW sewers containing domestic sewage, even if the industrial wastes would otherwise be considered hazardous.

The report (the Domestic Sewage Study, or DSS) was prepared by the EPA Office of Water and submitted to Congress on February 7, 1986. The DSS examined the nature and sources of hazardous wastes discharged to POTWs, measured the effectiveness of EPA's programs in dealing with such discharges, and recommended program improvements to achieve better control of hazardous wastes entering POTWs.

Implicit in the DSE is the assumption that the pretreatment program mandated by the CWA can ensure adequate control of industrial discharges to sewers. This program, detailed under Section 307(b) of the CWA and implemented in 40 CFR Part 403, requires EPA to establish pretreatment standards for pollutants discharged to POTWs by industrial facilities for those pollutants that interfere with, pass through, or are otherwise incompatible with the operation of POTWs.

As follow-up to the DSS, Section 3018(b) of RCRA directs the Administrator to revise existing regulations and promulgate any pretreatment standards controlling the discharge of individual hazardous constituents to POTWs that are necessary to ensure adequate protection of human health and the environment. These regulations are to be promulgated pursuant to RCRA, Section 307 of the CWA, or any appropriate authority possessed by EPA. The regulations must be promulgated within 18 months after submission of the DSS to Congress (i.e., by August 1987).

The DSS concluded that the DSE should be retained at the present time, and recommended improvements to various EPA programs under the CWA for better control of hazardous wastes entering POTWs. In addition, the DSS recommended study efforts to fill information gaps, and indicated that other statutes (e.g., RCRA and the Clean Air Act) should be considered along with the CWA to control either hazardous waste dischargers or receiving POTWs, or both (if the recommended research indicates the presence of problems not adequately addressed by the CWA).

One recommendation of the DSS was that EPA review and amend categorical pretreatment standards to achieve better control of the hazardous waste constituents. The DSS recommended that EPA modify existing standards to improve control of organic priority and non-priority pollutants, and also promulgate categorical standards for industrial categories not included in the Natural Resources Defense Council (NRDC) Consent Decree (NRDC v. Train, 8 ERC 2120, D.C.C., 1976).

Because the DSS identified hospitals as a possible source of hazardous pollutants, and hospital discharges to POTWs are unregulated for these pollutants, EPA decided to review and update existing data related to the discharge of both priority and hazardous non-priority pollutants from hospitals.

1.3 REGULATORY STATUS Previous hospital industry regulatory efforts resulted in the following measures:

- development of an industry profile
- sampling and analytical program to characterize water use and wastes
- assessment of control and treatment technologies
- development of final Best Practicable Technology (BPT) regulations.

The 1976 Development Document provided the technical basis for the interim final BPT limitations for biochemical oxygen demand (BOD5), total suspended solids (TSS), and pH, and proposed Best Available Technology (BAT) and NSPS for BOD5 and TSS. In 1981, the proposed BAT and NSPS for BOD5 and TSS were withdrawn.

1.4 SUMMARY OF METHODOLOGY

In this study, EPA directed its efforts primarily toward obtaining all available information on the discharge of priority and hazardous non-priority pollutants from hospitals. The data-gathering efforts and the subsequent information assessments conducted for this study were divided into eight tasks, which are discussed in the following sections.

1.4.1 REVIEW AND ASSESSMENT

A review of the existing wastewater data, compiled for the 1976 Development Document, was performed. This review indicated that very little effluent data were available on indirect discharging hospitals. The direct discharger data included conventional and some nonconventional pollutant data, but no priority or hazardous pollutant data. To comply with Section 3018(b) of RCRA, EPA initiated a sampling program designed to characterize hazardous waste discharge by the industry. This study concentrated on indirect dischargers because more than 97 percent of the hospitals are indirect dischargers and little or no information was available concerning them.

1.4.2 SUPPLEMENTAL DATA GATHERING

Following review of the existing data base, state regulatory agencies were contacted to obtain more effluent data from hospitals. The American Hospital Association (AHA) was then contacted, and they recommended that the American Society for Hospital Engineering (ASHE), an association within the AHA, be contacted. A meeting with ASHE was held in July 1986 to discuss the approach to information-gathering and hospital wastewater sampling. The recommendations received from ASHE were incorporated into the study. ASHE recommended other organizations and experts in the hospital engineering field, including the Centers for Disease Control (CDC) and the National Institutes for Health (NIH).

A literature search was performed to obtain current data on hospital waste generation and disposal practices. The generation, treatment, and disposal of hazardous waste was emphasized; specifically, the characterization of wastewater sources and the origin of wastewater contaminants. The literature used for this document was obtained from governmental and private sources. Data from the AHA Annual Survey of Hospitals were obtained to describe the industry population, services provided, and bed size (i.e., number of beds per hospital).

1.4.3 SUPPLEMENTAL QUESTIONNAIRE

Due to the lack of current data describing the hospital industry and in the event that further study of the hospitals might be desirable, a survey questionnaire was drafted in order to obtain pertinent information about the industry, such as the wastes produced and how hazardous wastes are handled and disposed of. An initial draft questionnaire was submitted to ASHE for review; comments were received and incorporated before completing the final draft. However, after review of the information and data presented in this document and in consideration of the fact that additional study efforts will not be required, the Agency has decided not to send a survey questionnaire to the hospital industry.

1.4.4 SAMPLING AND ANALYTICAL PROGRAM

A sampling program was conducted at four hospitals to screen for toxic and hazardous pollutants in hospital wastewater. The following criteria were developed to select the hospitals for sampling: (1) because of the lack of data concerning indirect discharges and EPA's need to comply with Section 3018(b) of RCRA, the hospitals should be indirect dischargers; and (2) because the average size of a U.S. hospital is approximately 200 beds, the sampled hospitals should be close to this size. As a result of input from ASHE, it was also decided that at least two of the sampled hospitals be research and teaching hospitals since these hospitals should represent a "worst case" situation in terms of both the variety and concentrations of toxic and hazardous pollutants.

Before sampling the hospitals, site visits were performed to confirm whether the criteria established for candidate hospitals were met. Since both hospitals satisfied the criteria, sampling episodes were conducted soon after the site visits. Each hospital's effluent was sampled for two consecutive days. The parameters analyzed included all compounds on the EPA ITD List of Analytes (see Appendix A). This list includes organic, inorganic, and conventional analytes. In addition, pH and temperature were recorded every four hours and settleable solids were analyzed once per day during the sampling episodes.

The preliminary data from these hospitals indicated that the worst-case scenario still needed to be represented. Therefore, with input from ASHE, two larger research and teaching hospitals were chosen for sampling, because the pollutant variety and concentrations were expected to be greater than at community hospitals.

The effluent samples from the research hospitals were analyzed for the same parameters as the samples from the community hospitals. However, preliminary results indicated that the research hospital effluent was not significantly different from the community hospital effluent. Results of the sampling episodes are discussed in Section 3.5.

1.4.5 INDUSTRIAL PROFILE AND SUBCATEGORIZATION

The detailed information collected in previous data gathering efforts by EPA and AHA was the basis for the industry profile. Information collected during the present study has been compared to earlier information to update and revise the industry profile and subcategorization scheme, as necessary.

1.4.6 WATER USE, SOLIDS GENERATION, AND WASTE CHARACTERIZATION

Both the data base established previously by EPA and the new data were reviewed to update water use and waste characterization for the industry. Literature was reviewed (see References) and information obtained during the data collection efforts was evaluated (including the sampling program and analytical data obtained from state and municipal authorities).

1.4.7 POLLUTANT PARAMETERS

The analytical data base was updated to include information obtained from previous industry studies in addition to the current data. To identify the pollutants of concern, the data base was reviewed with respect to levels and frequency of occurrence in the wastewater and waste solids (i.e., sludges) generated by the hospital industry.

1.4.8 ASSESSMENT OF CONTROL AND TREATMENT TECHNOLOGIES

Both previous and new waste treatment information on full-scale, pilot-scale, and laboratory-scale in-plant controls and treatment systems was evaluated. Literature on in-plant controls and treatment systems was also collected and reviewed.

SECTION 2.0

INDUSTRY PROFILE

2.1 SUMMARY

To be registered as a hospital, an institution must meet AHA requirements. However, membership in AHA is not a prerequisite for registration. According to the 1986 edition of the AHA Hospital Statistics, 6,872 hospitals were registered in the U.S. in 1985, with a total of 1,317,630 beds and staffed by 3,625,000 full-time personnel. These statistics compare to the 1975 totals of 7,156 hospitals, 1,466,000 beds, and 3,023,000 full-time employees. Currently, 152 hospitals with 13,639 beds are non-registered. Table 2-1 lists the 1985 distribution of registered hospitals by bed size.

Most of the hospitals can be classified as community hospitals, which are defined as nonfederal, short-term, general and special hospitals, excluding hospital units of institutions with facilities and services available to the public. Non-community hospitals include federal hospitals, long-term hospitals, hospital units of institutions, psychiatric hospitals, hospitals for tuberculosis and other respiratory diseases, chronic disease hospitals, institutions for the mentally retarded, and alcohol and chemical-dependency hospitals. There are 5,732 registered community hospitals compared to 1,140 registered non-community hospitals in the U.S.

The average size of community hospitals increased from 160 to 175 beds between 1975 and 1985. Community hospitals with less than 100 beds comprise 38 percent of the registered industry population. Moderately sized (i.e., 100 to 399 beds) community hospitals make up another 38 percent, and those with more than 400 beds make up approximately eight percent of the registered industry population. Table 2-2 compares the 1975 and 1985 distributions of community hospitals. There are 895 community hospitals affiliated with medical schools. Table 2-3 presents the distribution of these hospitals by bed size. The average size of registered noncommunity hospitals decreased from 441 beds in 1975 to 289 beds in 1985, due to the fact that there are 89 fewer noncommunity hospitals in 1985 than 1975, as well as the decreased number of long-term care facilities.

The number of direct and indirect dischargers also changed between 1975 and 1985. In 1975, there were over 7,000 hospitals, of which approximately 92 percent sent their waste to POTWs. The remaining hospitals treated their own waste. By 1985, the number of indirect dischargers had increased to include approximately 97 percent of the hospital industry.

TABLE 2-1
DISTRIBUTION OF REGISTERED HOSPITALS BY BED SIZE (1985)

TABLE 2-1

DISTRIBUTION OF REGISTERED HOSPITALS BY BED SIZE (1985)

Classification (Beds)	No. of Hospitals	Beds
6-24	267	5,066
25-49	1,134	42,310
50-99	1,666	120,854
100-199	1,618	228,844
200-299	848	206,261
300-399	507	175,773
400-499	301	134,387
500 or more	531	404,135

Source: AHA Hospital Statistics; 1986 Edition; Table 8

TABLE 2-2

DISTRIBUTION OF COMMUNITY HOSPITALS, 1975 TO 1985

Bed Size Category and Census Division	Number of Hospitals 1975	1985	Percent Change
Total Community Hospitals	5,875	5,732	- 2.4
Bed Size Category			
6-24	299	208	-30.4
25-49	1,155	982	-15.0
50-99	1,481	1,399	- 5.5
100-199	1,363	1,407	3.2
200-299	678	739	9.0
300-399	378	439	16.1
400-499	230	239	3.9
500 or more	291	319	9.6
Census Division			
New England	265	248	- 6.4
Middle Atlantic	663	596	-10.1
South Atlantic	791	826	4.4
North Central	1,727	1,669	- 3.4
South Central	1,319	1,325	0.5
Mountain	356	375	5.3
Pacific	754	693	- 8.1

Source: AHA Hospital Statistics; 1986 Edition; Table 2

TABLE 2-3

DISTRIBUTION OF REGISTERED COMMUNITY HOSPITALS AFFILIATED WITH MEDICAL SCHOOLS BY BED SIZE (1985)

Classification (Beds)	No. of Hospitals
Less than 300	294
300-399	187
400-499	149
500 or more	265

Source: AHA Hospital Statistics: 1986 Edition; Table 8

2.2 STANDARD PROCESSES AND PRACTICES

The main function of a hospital is to provide health care to the people of a community; its size will depend on the population that it plans to serve. Some hospitals provide services other than health care, including research, teaching, long-term health care, and nursing home facilities. In addition, specialty hospitals deal with specific types of illnesses, such as psychiatric disorders, tuberculosis and respiratory diseases, alcohol or chemical dependency, and obstetrics.

Regardless of the type of facility, activities are similar in all hospitals. Most hospitals are open 24 hours a day, 365 days a year, with most activities continuing around the clock. A hospital must be able to provide the necessary support facilities for the staff, as well as patients and their visitors, including surgical suites, patient rooms, laboratories, cafeterias, laundries, restrooms, heating and air conditioning units, and other support systems. These services all require a reliable water supply.

According to the 1976 Development Document, hospitals use water at a rate of 242 gallons per bed per day. (Based on the latest information, this figure has not changed.) This water is discharged to either the municipal sanitary system or the hospital's own treatment system. Solid waste generated in hospitals can either be treated on-site or transported off-site for disposal in a secured landfill. The main method of on-site treatment is incineration; the resulting ash is transported to a secured landfill for final disposal.

SECTION 3.0

3.0 WASTE CHARACTERIZATION

Wastes generated in hospitals can be classified as either general (i.e., nonhazardous) or hazardous waste. Approximately 85 percent of the total hospital wastestream can be classified as general, with the remainder classified as hazardous waste (ASHE, 1985). The types of hazardous waste generated include chemical, radioactive, infectious, and physically hazardous, or a combination of these. The primary sources of wastewater in hospitals include sanitary wastewater and discharges from surgical rooms, laboratories, laundries, X-ray departments, cafeterias, and glassware washing.

In 1976, EPA investigated the need for establishing subcategories to determine if segments of the hospital industry existed in which separate effluent limitations and standards might apply. EPA considered and assessed the following factors: the size, age, location, and type of hospital; the nature of wastes generated; and the treatability of wastewater. EPA found that the wastewater characteristics of the hospitals studied were very similar and independent of these factors. EPA concluded in the 1976 Development Document that further subcategorization was not required to establish effluent limitations guidelines and NSPS for the hospital industry. Based on industry sampling, review of the 1976 document, and literature searches, no fundamental changes in the industry have occurred since the 1976 document indicating the need for further subcategorization.

3.1 CHEMICAL WASTE

Chemical wastes generated in hospitals consists of spent solvents, acidic and caustic solutions, and solutions containing heavy metals. Solid chemical wastes include organic and inorganic compounds and heavy metals. The amount of chemical hazardous waste generated by the hospital industry is summarized in Table 3-1 (ASHE, 1985).

Most of the solvents used by the hospitals category are used at research and teaching hospitals. The solvents used most frequently include alcohols, xylenes, formalin (i.e., formaldehyde in ethyl alcohol), and toluene. Alcohols and xylenes are used in the histology processing operations in both clinical and research laboratories. Formalin is used as a preservative in pathology departments. Toluene is used in liquid scintillation and can be radioactive when used for this purpose. Other solvents that contribute to the waste load include halogenated solvents used primarily for degreasing or cleaning equipment, and acetone used for cleaning glassware.

TABLE 3-1
CHEMICAL HAZARDOUS WASTE GENERATED BY HOSPITAL INDUSTRY

Hospitals	Chemical Hazardous Waste Output	Extrapolation of Data for all Hospitals with Certified Capacity of			
		Under 100 Beds	100 to 200 Beds	200 to 400 Beds	Over 400 Beds
91%	Under 100 Kg/month	2,625 hospitals	1,227 hospitals	988 hospitals	460 hospitals
6%	100 to 500 Kg/month	45 hospitals	158 hospitals	96 hospitals	43 hospitals
2%	500 to 1000 Kg/month	0 hospitals	0 hospitals	36 hospitals	60 hospitals
1%	Over 1000 Kg/month	0 hospitals	17 hospitals	24 hospitals	34 hospitals
100%	All Hospitals	2,670 Hospitals	1,402 Hospitals	1,444 Hospitals	597 Hospitals

Note: Extrapolation based on assumption that all hospital beds are occupied.

Solutions containing heavy metals are used and produced in hospitals. Spent solution produced in the X-ray developing process contains silver. Certain medicines, disinfectants, mildew inhibitors, and thermometers contain mercury. Arsenic is used in laboratories in chemical reactions and can be used to kill cells.

Solid chemical wastes include both organic and inorganic compounds, most of which are generated in laboratories. These compounds include salts, precipitates from various chemical reactions, metals, and solid chemicals with expired shelf-lives.

3.2 RADIOACTIVE WASTE

Nuclear medicine is practiced in nearly every hospital; approximately 25 percent of the total low level radioactive waste generated in the U.S. originates from clinical practice and biomedical research (Olsen, 1985). Medical uses of radioisotopes are common and varied (Table 3-2) (Brill, 1985).

The types of radioisotopes used will vary depending on whether a hospital is affiliated with research or specialized in certain treatments, or is relatively small and concerned with general health care. The following radioisotopes used in hospitals have low radioactive levels and most have short half-lives:

H^{3} S^{35} Ga^{67} Yb^{169} Co^{57} C^{14} Ca^{45} Tl^{201}

I^{131} Co^{58} P^{33} Cr^{51} Xe^{133} I^{123} I^{125} Mo^{99}

In^{111} Tc^{99}

Low-level wastes can be solid, liquid, or gaseous radioactive products from a variety of medical processes. These wastes include paper, absorbed liquids, protective clothing, contaminated plastics, tools, sealed sources (e.g., radium needles), biological wastes, laboratory animal carcasses, scintillation vials and liquids, needles and syringes, and other contaminated handling materials.

3.3 INFECTIOUS WASTE

In most hospitals, 10 to 15 percent of the total waste stream is generally classified as infectious. However, depending on the definition used by hospital management, the contribution may be as high as 30 to 40 percent (ASHE, 1980). Most infectious waste consists of contaminated synthetic materials, such as disposable plastic tubing and paper products. Opinion varies on what should be designated as infectious waste; Table 3-3 summarizes various waste types as designated by the EPA, CDC, and Joint Commission on Accreditation of Hospitals (JCAH). The "Other" category includes linens, paper and plastic products, and items that may have been in contact with a patient considered to have an infectious disease.

TABLE 3-2

USE OF RADIOISOTOPES IN PATIENT CARE
1983 AND 1984

Sources	No. of Annual Procedures	No. Percent of Hospitals
Nuclear Medicine Imaging (B)	6,130,000 (A)	3,830 (60.3)
Radioimmunoassay (C)	54,800,000 (C)	4,500 (70.9)
Isotopic Radiation Therapy (B)	61,000 (S)	1,390 (21.9)

(A) Estimate of Market Measures, Inc., West Orange, New Jersey
(B) Statistics from American Hospital Association, 1984
(C) Statistics from Luning Prat Associates, Montrail, New Jersey
(D) Estimate by Commission on Professional and Hospital Activities, Ann Arbor, Michigan (inpatient only)

TABLE 3-3

DESIGNATION OF INFECTIOUS WASTE TYPES

Waste Type or Source Type	CDC(1)	JCAH(2)	EPA(3)
Microbiological			
Blood and Blood Products	Yes	Yes	Yes
Communicable Disease Isolation	Yes	Yes	Yes
Pathological (including Autopsy)	Yes	Yes	Yes
Items containing Secretions/Excretions	Yes	Yes	No*
Contaminated Laboratory Wastes	No	Yes	No*
Sharps	Yes	Yes	Yes
Surgical ("Dirty" Cases)	No	Yes	No*
Dialysis Unit	No	Yes	No*
Other	No	No	No*

* EPA regards these waste types as "optional " infectious wastes, that is, the individual facility should decide whether the waste in question is infectious.

(1) Garner, J.S. and Favero, M.S. Guideline for Handwashing and Hospital Environmental Control; Centers for Disease Control; November 1985.

(2) Personal Communication, March 7, 1989, Nan Bangs (E.C. Jordan Co.) Ode Keil (Joint Communication On Accredation of Hospitals), referencing Joint Commission on Accredation of Hospitals, "Managing Hazardous Materials"; Plant, Technology, and Safety Management Series; 1986.

(3) U.S. EPA EPA Guide for infectious Waste Management; Office of Solid Waste and Emergancy Response; USEPA 530-SW-86-014; May 1986

3.4 PHYSICALLY HAZARDOUS MATERIALS

Physically hazardous waste generated at hospitals includes pressurized containers and sharps. Pressurized containers consist of bottles, cans, or tanks containing gases, and aerosols or chemicals that are under pressure and could explode if handled improperly. Sharps consist of needles, scalpels, syringes, broken glass, and anything capable of causing cuts or puncture wounds.

3.5 WASTEWATER

Approximately 242 gallons of wastewater per bed per day is produced in hospitals (AHA, 1976). Wastewater from hospitals is essentially domestic (i.e., sanitary wastewater from residential and commercial sources), and is characterized by pollutant concentrations of BOD5, chemical oxygen demand (COD), TSS, and total organic carbon (TOC) in the following approximate ranges:

BOD5 = 50 to 400 mg/l
COD = 150 to 800 mg/l
TSS = 60 to 200 mg/l
TOC = 50 to 300 mg/l

Contaminants that may appear in hospital wastewater include metals, solvents, radioisotopes, and body fluids (considered by some authorities to be infectious). The characteristics of the discharged wastewater may be affected by the various pollution control practices used within the hospital.

Many different types of solvents, metals, and chemical products are introduced to the wastestream. However, because hospitals use and discharge relatively large amounts of water, most pollutants are diluted to concentrations similar to domestic wastewater. Table 3-4 compares the ranges of pollutants detected in sampled hospital wastewater to wastewater with less than ten percent industrial contribution entering various POTWs around the country. This comparison indicates that, except for a few compounds i.e., acetone, silver, phenol, mercury, and barium), the wastewater falls into the range observed for nonindustrial wastewater.

TABLE 3-4

Hospital Effluents Compared With Nonindustrial POTW Influents

Pollutant	Range of Concentrations Found in 14 Nonindustrial POTW Influents*	Range of Concentrations Found in 4 Sampled Hospitals
Volatile Organics		
Acetone	----	<50 - 1,721 ppb
Benzene	0 - 33 ppb	<10 - 104
Bromodichloromethane	<1 - <5	<10 - 30
Chloroform	1 - 38	<10 - 24
Toluene	5 - 283	<10 - 23
1,1-Dichloroethane	<1 - <10	<10 - 38
Semivolatile Organics		
Benzoic Acid	----	<10 - 789 ppb
o-Cresol	----	<10 - 11
Phenol	<1 - 260 ppb	<110 - 405
alpha-Terpineol	----	<10 - 174
4-Nitrophenol	50	<50 - 83
Priority Pollutant Metals		
Cadmium	1 - 9 ppb	<5 - <10 ppb
Chromium	1 - 159	<3 - 140
Copper	21 - 330	<25 - 105
Lead	16 - 194	<50 - <200
Mercury	0.2 - 1.7	<0.2 - 4.5
Nickel	4 - 64	<12 - 42
Silver	1 - 45	2.7 - 140
Zinc	89 - 806	25 - 227
Common Ions		
Calcium	8 - 90 ppm	7.9 - 204.0 ppm
Iron	679 - 13,074	84 - 3,080
Magnesium	1 - 36	0.9 - 9.2
Sodium	41 - 208	11 - 240
Elements		
Aluminum	537 - 6540 ppb	90 - 1670 ppb
Barium	53 - 395	26 - 1680
Boron	136 - 561	35 - 207
Manganese	28 - 301	2 - 184
Molybdenum	<35 - 140	<10 - 140
Titanium	7 - 157	10 - <50

TABLE 3-4 (Continued)

Hospital Effluents Compared With Nonindustrial POTW Influents

Pollutant	Range of Concentrations Found in 14 Nonindustrial POTW Influents*	Range of Concentrations Found in 4 Sampled Hospitals
Conventional		
BOD5	95 - 329 ppm	23 - 340 ppm
TSS	85 - 508	170 - 3900
O&G	13 - 75	7.5 - 99.0
Nonconventionals		
COD	183 - 867 ppm	98 - 1000 ppm
TOC	47 - 265	24 - 190
NH_3/N	4 - 24	2.2 - 8.1

* The industrial contributions to the 14 POTWs ranged from one to ten percent. The median industrial contribution was six percent.

Chemicals may enter the wastewater directly as a result of disposal in laboratory sinks, as well as a result of accidental spills in laboratories or chemical storage areas. The radioisotopes that may enter wastewater directly as a result of patient excretion after treatment are not regulated. Some isotopes are sewered after dilution or after they have decayed to a specified, allowable level. The concentrations of radioisotopes from these sources are very low and the radioisotopes generally have short half-lives. Disposal of radioisotopes in this manner is regulated by the Nuclear Regulatory Commission, in addition to certain state and local authorities.

Waste considered infectious may also appear in hospital wastewater. Table 3-3 summarizes various designations of infectious waste types by the EPA, CDC, and JCAH. Some of the waste listed as infectious will be disposed of in the hospital wastewater because of recommendations by CDC or JCAH. Table 3-5 summarizes the recommended disposal methods for the various infectious waste types and sources.

Currently, no federal regulations govern the disposal of infectious waste; however, certain local or state regulations do apply. The EPA, CDC, and JCAH have each developed guidelines, summarized in Table 3-5. Currently, hospital management decides which guidelines or combination of guidelines to follow, unless tney are regulated by a local or state authority.

Specific pollutants may be present in hospital wastewater in levels greater than expected from domestic wastewater (i.e., silver, barium, sodium, and acetone). Figure 3-1 is a schematic of the sampling point locations for all sampling episodes. Analytical data summaries for each hospital sampled are presented in the following sections, along with brief descriptions of the hospitals. To maintain confidentiality, each facility is identified by a code letter.

3.5.1 HOSPITAL A

This facility, located in New England, is a 325 bed hospital serving the surrounding community. Water is supplied by an on-site well and is softened before use. The various sources of wastewater at this hospital include patient rooms, laboratories, the X-ray department, the cafeteria, surgical suites, the cooling water system, and sanitary wastewater. Laundry is processed off-site by a private contractor. On-site waste treatment at this facility consists of specific unit operations, depending on the objective. These include grease traps in the cafeteria, acid neutralization tanks in the laboratories, a plaster recovery tank in the room designated for fitting casts, and a silver recovery system in the X-ray department. Sewered wastewater is treated at a municipal treatment plant. Three raw wastewater samples were

TABLE 3-5

INFECTIOUS WASTE DISPOSAL METHOD RECOMMENDATIONS

WASTE TYPE OR SOURCE	CDC	JCAH(3)	EPA(4)
Microbiological	I,S(1)	I,S	D,I,S,T
Blood and Blood Products	I,S,W(1)	L,W	D,I,M,S
Communicable Disease Isolation	H(2)	L,W	I,S
Pathological (including Autopsy)	I(1)	C,I	A,C,I
Items containing Secretions/Excretions	N(1)	L,W	I,S
Contaminated Laboratory Wastes	I,S,G(1)	I,S	A,I,S
Sharps	N(1)	I,S	I,S
Surgical ("Dirty" Cases)	N(1)	I,S	I,S
Dialysis Unit	N(1)	I,S	I,S
Other	N(1)	N	A,I,S

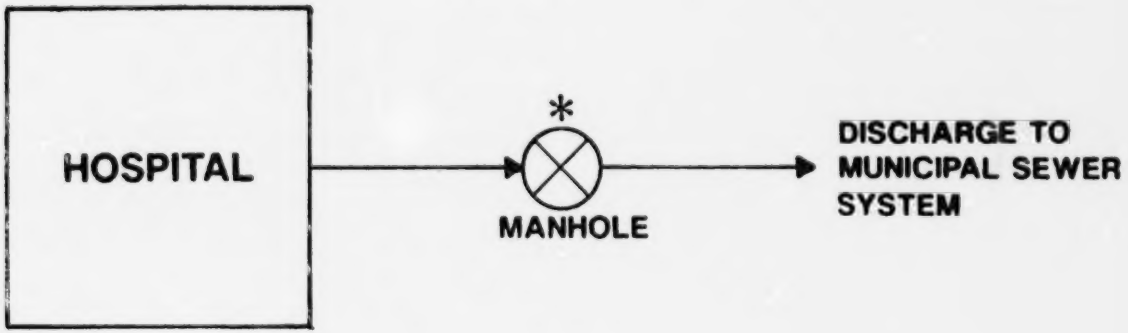
Key: A - steam sterilization with incineration of grinding
C - cremation or burial by mortician
D - chemical disinfection
G - general hospital solid waste in puncture-resistant packaging
H - according to hospital policy
I - incineration
L - sanitary landfill
M - discharge to a sanitary sewer for treatment in municipal sewer systems (provided secondary treatment is available)
N - not considered infectious waste
S - steam sterilization
T - thermal inactivation

(1) Garner, J.S. and Favero, M.S. Guideline for Handwashing and Hospital Environmental Control; Centers for Disease Control; November 1985

(2) Garner J,S, and Simmons, B.P "CDC Guidelines for Isolation Precautions in Hospitals", Infection Control; No. 5, pp. 245-325.

(3) Personal Communication, March 7, 1989, Nan Bangs (E.C. Jordan Co.) and Ode Keil (Joint Commission on Accreditation of Hospitals), referencing Joint Commission on Accreditation of Hospitals, "Managing Hazardous Materials"; Plant, Technology, and Safety Management Series; 1986

(4) USEPA, EPA Guide For Infectious Waste Management; Office of Solid Waste and Emergency Response; USEPA 530-SW-86-014; May 1986.



KEY

* SAMPLE POINT

FIGURE 3-1
HOSPITAL SAMPLING POINT
SCHEMATIC

collected from a manhole in the sewer line located in a parking lot behind the hospital. Results of sample analysis for pollutants detected at least once are summarized in Table 3-6. As indicated, low concentrations of only a few organic pollutants were detected in the raw wastewater samples. Concentrations of metals and conventional pollutants were in the range typical of nonindustrial wastewater. The hospital engineer indicated that the water associated with this facility would have a high level of sodium, which was evident in the results.

3.5.2 HOSPITAL B

This facility, also located in New England, is a research and teaching hospital with 232 beds. Water is supplied by the local municipality. Wastewater sources at this hospital include patient rooms, laboratories, the cafeteria, the X-ray department, cooling water, surgical suites, and the sanitary sewer. Laundry is processed off-site by a private contractor. The hospital discharged approximately 300,000 gallons per day of wastewater during each day of sampling.

On-site wastewater treatment controls used at this hospital include grease traps in the kitchen, limestone neutralization tanks for laboratory wastewater, and silver recovery for the large X-ray facilities. Sewered wastewater is treated off-site at a municipal treatment facility. Two raw wastewater samples were collected from a manhole in the sewer line located in a grassy area along the main entrance road to the hospital. Tap water samples were obtained from a faucet in a storage building located near the manhole used for sampling.

Table 3-7 summarizes the results of analysis for samples collected at this facility. The only organic compounds detected were acetone and chloroform, in detectable concentrations. Concentrations of conventional pollutants and metals (except silver) were in the range typical of nonindustrial wastewater. Silver was detected at approximately twice the level expected in nonindustrial wastewater; this is probably due to silver originating in the X-ray department.

3.5.3 HOSPITAL C

This hospital, located in the southeastern U.S., is a research and teaching facility with 456 beds. Water is supplied by the local municipality. Major contributors to the wastestream include the laboratories, cafeteria, X-ray and photography departments, patient rooms, laundry, surgical suites, and sanitary waste. Average flow from the hospital and the research areas is unknown; however, it is estimated that 80 percent originates in the hospital and 20 percent in the research buildings. In-house wastewater treatment techniques used at this hospital include dilution or decay of liquid low-level radioactive compounds (holding) prior to discharge, in accordance with state and federal guidelines. No other types of treatment are used prior to discharge to the

TABLE 3-6
SUMMARY OF REPORTED ANALYTICAL RESULTS
HOSPITAL A

Pollutant Category and Pollutant	Units	Blank Sample	Tap Water (15202)	Raw Waste (15192)	Raw Waste (15193)	Raw Waste (15195)
Type 1 Organics						
alpha-terpineol	µg/ℓ	--	--	--	174	169
benzene	µg/ℓ	--	--	--	91	104
2-chloronaphthalene	µg/ℓ	--	42	--	--	--
Type 2 Organics						
benzoic acid	µg/ℓ	--	--	789	--	--
Pesticides/Herbicides						
dichloran	µg/ℓ	--	NA	1.5t	--	11t
etridazone	µg/ℓ	--	NA	--	--	0.8t
Purgeable Organic Compounds	mg/ℓ	NA	--	--	3.6	0.72
Dioxins/Furans			-NOT ANALYZED-			
Metals						
calcium	µg/ℓ	NA	NA	48,800	76,000	90,000
magnesium	µg/ℓ	NA	NA	4,900	7,800	9,200
sodium	µg/ℓ	NA	NA	100,000	210,000	240,000
aluminum	µg/ℓ	NA	NA	110	110	170
manganese	µg/ℓ	NA	NA	2	4	4
boron	µg/ℓ	NA	NA	48	69	59
barium	µg/ℓ	NA	NA	140	65	400
molybdenum	µg/ℓ	NA	NA	27	130	140
copper	µg/ℓ	NA	NA	62	58	72
iron	µg/ℓ	NA	NA	130	34	170

TABLE 3-6 (cont.)

Pollutant Category and Pollutant	Units	Blank Sample	Tap Water (15202)	Raw Waste (15192)	Raw Waste (15193)	Raw Waste (15195)
Metals (continued)						
titanium	µg/ℓ	NA	NA	10	20	20
zinc	µg/ℓ	NA	NA	92	26	41
silver	µg/ℓ	NA	NA	2.7	13	7.6
osmium	µg/ℓ	NA	NA	--	NA	NA
Elements						
arsenic		NA	DET	DET	DET	DET
germanium		NA	DET	--	--	DET
iodine		NA	--	--	DET	DET
phosphorus		NA	--	DET	DET	DET
sulfur		NA	DET	DET	DET	DET
silicon		NA	DET	DET	DET	DET
Classical Pollutants						
Residue, filterable	mg/ℓ	NA	NA	460	1,800	3,900
Residue, non-filterable	mg/ℓ	NA	NA	48	18	99
Ammonia, as N	mg/ℓ	NA	NA	2.2	3.4	3.0
Nitrogen, Kjeldahl, total	mg/ℓ	NA	NA	25	18	17
Nitrate-nitrite, as N	mg/ℓ	NA	NA	0.2	0.12	--
Total phosphorus, as P	mg/ℓ	NA	NA	1.1	1.9	2.2
BOD 5-day (carbonaceous)	mg/ℓ	NA	NA	76	23c	58c
Chemical oxygen demand	mg/ℓ	NA	NA	120	98	130
Oil and grease, total recoverable	mg/ℓ	NA	NA	7.5c	10c	12c
Total organic carbon	mg/ℓ	NA	NA	29	24	29

-- Indicates pollutant concentration below detection limit
NA Indicates not analyzed
DET Indicates pollutant concentrations qualitatively detected
t Denotes tentative identification below the detection limit
c Average of grab sample results

TABLE 3-7
SUMMARY OF REPORTED ANALYTICAL RESULTS
HOSPITAL B

Pollutant Category and Pollutant	Units	Blank Sample	Tap Water (15232)	Raw Waste (15230)	Raw Waste (15231)
Type 1 Organics					
acetone	µg/ℓ	--	--	1,721	129
chloroform	µg/ℓ	--	15	--	--
Type 2 Organics			-NONE DETECTED-		
Pesticides/Herbicides			-NOT ANALYZED-		
Purgeable Organic Compounds	mg/ℓ	NA	--	0.14	1.2
Dioxins/Furans			-NOT ANALYZED-		

TABLE 3-7 (cont.)

Pollutant Category and Pollutant	Units	Blank Sample	Tap Water (15232)	Raw Waste (15230)	Raw Waste (15231)
Metals					
calcium	µg/ℓ	NA	6,000	8,400	7,900
magnesium	µg/ℓ	NA	660	1,100	980
sodium	µg/ℓ	NA	2,800	12,000	11,000
aluminum	µg/ℓ	NA	--	90	180
manganese	µg/ℓ	NA	--	12	10
lead	µg/ℓ	NA	--	91	--
boron	µg/ℓ	NA	12	55	35
barium	µg/ℓ	NA	10	26	41
molybdenum	µg/ℓ	NA	--	16	--
chromium	µg/ℓ	NA	--	140	9
copper	µg/ℓ	NA	1,100	120	82
iron	µg/ℓ	NA	--	390	470
nickel	µg/ℓ	NA	--	13	--
titanium	µg/ℓ	NA	20	19	21
zinc	µg/ℓ	NA	290	71	64
silver	µg/ℓ	NA	--	75	12
mercury	µg/ℓ	NA	--	0.69	1.1

TABLE 3-7 (cont.)

Pollutant Category and Pollutant	Units	Blank Sample	Tap Water (15232)	Raw Waste (15230)	Raw Waste (15231)
Elements					
phosphorus		NA	--	DET	DET
sulfur		NA	DET	DET	DET
silicon		NA	DET	DET	DET
Classical Pollutants					
Residue, filterable	mg/ℓ	NA	NA	200	170
Residue, non-filterable	mg/ℓ	NA	NA	43	27
Fluoride	mg/ℓ	NA	NA	0.78	0.82
Ammonia, as N	mg/ℓ	NA	NA	3.5	2.7
Nitrogen, Kjeldahl, total	mg/ℓ	NA	NA	19	15
Nitrate-nitrite, as N	mg/ℓ	NA	NA	0.13	0.22
Total phosphorus, as P	mg/ℓ	NA	NA	2.0	2.1
BOD 5-day (carbonaceous)	mg/ℓ	NA	NA	63	63
Chemical oxygen demand	mg/ℓ	NA	NA	160	170
Oil and grease, total recoverable	mg/ℓ	NA	NA	12c	15c
Total organic carbon	mg/ℓ	NA	NA	63	52

- Indicates pollutant concentration below detection limit
NA Indicates Not Analyzed
DET Indicates pollutant concentration qualitatively detected
c Average of grab sample results

municipal sewer system. Two raw samples were collected from a manhole in the sewer line into which wastewater from the hospital and research areas flows before discharge to the city sewer. Results of analysis for samples collected at this facility are presented in Table 3-8. Review of the data shows that relatively low concentrations of eight organic compounds were detected in the raw wastewater. Silver and barium were detected at levels greater than typical nonindustrial wastewater. This is probably due to discharge from the X-ray and photography laboratories. Conventional pollutants were detected in the range typical of nonindustrial wastewater.

3.5.4 HOSPITAL D

This eastern U.S. research and teaching hospital has 452 beds. Water is supplied by the local municipality. sources of the wastewater stream include the laboratories, laundry, cafeteria, X-ray and photography departments, patient rooms, surgical suites, and sanitary sewer. The average flow of wastewater from the research and hospital areas is unknown.

In-house waste treatment techniques employed at this hospital include solvent recovery of xylene and ethanol, as well as grease traps located in the cafeteria. With solvent recovery, xylene and ethanol are distilled; the pure product is reused, while the impure product is sent to the hospital's hazardous waste department for appropriate disposal.

Raw wastewater samples were collected from a manhole located next to the hospital main entrance; the analysis results are summarized in Table 3-9. Review of the data show concentrations of only three organic compounds. Metals detected were in the range typical of nonindustrial wastewater except for silver, which was found at greater levels, probably due to discharge from the X-ray and photography departments.

TABLE 3-8
SUMMARY OF REPORTED ANALYTICAL RESULTS
HOSPITAL C

Pollutant Category and Pollutant	Units	Blank Sample	Tap Water (15674)	Raw Waste (15620)	Raw Waste (15673)
Type 1 Organics					
acetone	µg/ℓ	--	--	--	948
bromodichloromethane	µg/ℓ	--	--	--	38
chloroform	µg/ℓ	--	--	24	17
toluene	µg/ℓ	--	--	--	23
1,1-dichloroethane	µg/ℓ	--	--	38	--
4-nitrophenol	µg/ℓ	--	--	--	83
Type 2 Organics					
o-cresol	µg/ℓ	--	--	11	--
thioxanthone	µg/ℓ	422	--	--	--
Pesticides/Herbicides			-NOT ANALYZED-		
Purgeable Organic Compounds			-NOT ANALYZED-		
Dioxins/Furans			-NOT ANALYZED-		

TABLE 3-8 (cont.)

Pollutant Category and Pollutant	Units	Blank Sample	Tap Water (15674)	Raw Waste (15620)	Raw Waste (15673)
Metals					
calcium	µg/ℓ	NA	10,400	16,000	16,200
magnesium	µg/ℓ	NA	1,380	3,710	2,560
sodium	µg/ℓ	NA	18,400	88,200	80,200
aluminum	µg/ℓ	NA	372	1,670	1,120
manganese	µg/ℓ	NA	--	184	24
boron	µg/ℓ	NA	141	307	182
barium	µg/ℓ	NA	--	1,680	369
chromium	µg/ℓ	NA	--	139	--
copper	µg/ℓ	NA	42	105	75
iron	µg/ℓ	NA	83	3,080	1,190
zinc	µg/ℓ	NA	--	227	203
silver	µg/ℓ	NA	--	89.0	31.0
mercury	µg/ℓ	NA	--	--	0.4
osmium	mg/ℓ	NA	--	0.1	--
Elements					
iodine	mg/ℓ	NA	--	6	--
phosphorus	mg/ℓ	NA	--	9	7
potassium	mg/ℓ	NA	--	2.2	2.0
strontium	mg/ℓ	NA	--	0.1	--
silicon	mg/ℓ	NA	1	2	1
sulfur	mg/ℓ	NA	10	33	24

TABLE 3-8 (cont.)

Pollutant Category and Pollutant	Units	Blank Sample	Tap Water (15674)	Raw Waste (15620)	Raw Waste (15673)
Classical Pollutants					
Residue, filterable	mg/ℓ	NA	NA	520	500
Residue, non-filterable	mg/ℓ	NA	NA	280	620
Cyanide, total	µg/ℓ	NA	NA	28	--
Fluoride	mg/ℓ	NA	NA	1.4	1.6
Ammonia, as N	mg/ℓ	NA	NA	8.1	7.3
Nitrogen, Kjeldahl, total	mg/ℓ	NA	NA	51	36
Nitrate-nitrite, as N	mg/ℓ	NA	NA	--	0.053
Total phosphorus, as P	mg/ℓ	NA	NA	5.8	7.1
BOD 5-day (carbonaceous)	mg/ℓ	NA	NA	340	200
Chemical oxygen demand	mg/ℓ	NA	NA	1,000	700
Oil and grease, total recoverable	mg/ℓ	NA	NA	99	32
Total organic carbon	mg/ℓ	NA	NA	190	190
Sulfide, total (iodometric)	mg/ℓ	NA	NA	2.5	--

-- Indicates pollutant concentrations below detection limit
NA Indicates not analyzed

TABLE 3-9
SUMMARY OF REPORTED ANALYTICAL RESULTS
HOSPITAL D

Pollutant Category and Pollutant	Units	Blank Sample	Tap Water (15682)	Raw Waste (15676)	Raw Waste (15679)
Type 1 Organics					
acetone	µg/ℓ	--	--	596	1,612
chloroform	µg/ℓ	--	--	13	--
phenol	µg/ℓ	--	--	26	405
Type 2 Organics			-NONE DETECTED-		
Pesticides/Herbicides			-NONE ANALYZED-		
Purgeable Organic Compounds			-NONE ANALYZED-		
Dioxins/Furans			-NOT ANALYZED-		
Metals					
calcium	µg/ℓ	NA	18,300	19,400	20,400
magnesium	µg/ℓ	NA	2,400	3,150	3,000
sodium	µg/ℓ	NA	4,910	27,200	38,600
manganese	µg/ℓ	NA	--	--	19
boron	µg/ℓ	NA	--	134	--
barium	µg/ℓ	NA	--	69	99
chromium	µg/ℓ	NA	--	--	30
copper	µg/ℓ	NA	--	--	28
iron	µg/ℓ	NA	--	--	672
nickel	µg/ℓ	NA	--	--	--
zinc	µg/ℓ	NA	42	40d	124
silver	µg/ℓ	NA	5.0	8.0R	140.0
mercury	µg/ℓ	NA	--	0.9	4.5

TABLE 3-9 (cont.)

Pollutant Category and Pollutant	Units	Blank Sample	Tap Water (15682)	Raw Waste (15676)	Raw Waste (15679)
Elements					
lithium	µg/ℓ	NA	--	--	4
phosphorus	µg/ℓ	NA	--	--	4
silicon	µg/ℓ	NA	--	--	2
strontium	µg/ℓ	NA	0.2	0.2	0.2
sulfur	µg/ℓ	NA	10	16	19
Classical Pollutants					
Residue, filterable	mg/ℓ	NA	NA	230	310
Residue, non-filterable	mg/ℓ	NA	NA	93	75
Fluoride	mg/ℓ	NA	NA	1.0	1.1
Ammonia, as N	mg/ℓ	NA	NA	4.1	3.3
Nitrogen, Kjeldahl, total	mg/ℓ	NA	NA	20	1.6
Nitrate-nitrite, as N	mg/ℓ	NA	NA	0.33	0.076
Total phosphorus, as P	mg/ℓ	NA	NA	3.5	3.1
BOD 5-day (carbonaceous)	mg/ℓ	NA	NA	100q	130
Chemical oxygen demand	mg/ℓ	NA	NA	290	310
Oil and grease, total recoverable	mg/ℓ	NA	NA	9.5c	24c
Total organic carbon	mg/ℓ	NA	NA	37	45
Sulfide, total (iodometric)	mg/ℓ	NA	NA	2.1c, NR	1.1c

-- Indicates pollutant concentration below detection limit
NA Indicates not analyzed
q "Qualified" value
NR Matrix interference
c Average of grab sample results
d Indicates duplicate analysis is not within control limits
R Spike recovery is not within control limits

3.6 POLLUTANTS

3.6.1 INTRODUCTION

The traditional, priority, and hazardous non-priority pollutants characterized in Section 3.0 are discussed in this section relative to their occurrence in the hospital industry's wastewater.

3.6.2 TRADITIONAL POLLUTANTS

The CWA requires the Administrator to establish effluent limitations, guidelines, and standards for traditional pollutants. Among these conventional parameters (i.e., BOD_5, TSS, fecal coliform, pH, and oil and grease) and nonconventional parameters (i.e., COD, TOC, color, ammonia, radioactivity, nitrogen, and phosphorus) were considered. BOD_5 and TSS were the parameters chosen in past rulemaking efforts as representative of specific and persistent pollutant problems across the industry; data collected in the recent sampling program do not change this conclusion. These pollutant parameters were identified in 100 percent of the hospital effluents for which data were obtained in both past and recent sampling episodes.

3.6.3 PRIORITY POLLUTANTS

The priority pollutants detected in hospital wastewater as a result of the ITD/RCRA Sampling and Analysis Program are listed in Table 3-10. Analytical results for the detected priority pollutants are discussed in Section 3.6.6

3.6.4 HAZARDOUS NONPRIORITY POLLUTANTS

The hazardous nonpriority pollutants detected in hospital wastewater as a result of the ITD/RCRA Sampling and Analysis Program are listed in Table 3-11. The pollutants are listed on the ITD List of Analytes; however, they are not priority pollutants. Analytical results for the detected hazardous nonpriority pollutants are discussed in Section 3.6.6.

3.6.5 INDUSTRY MASS LOADINGS

Table 3-12 presents raw data from the indirect dischargers by pollutant group as identified in tables 3-10 and 3-11.

Three averages were calculated for each pollutant. The first (Method A) was an average calculated by including the detected pollutant concentration and considering the less-than-detection-limit values as zero. The second (Method B) was an average calculated by including both the absolute value of detection limit that was reported when a "not detected" (ND) was given and the actual detected pollutant concentration. The third (Method

Table 3-10

PRIORITY POLLUTANTS DETECTED

Volatile Organics	Semivolatile Organics
Benzene	Phenol
Bromodichloromethane	4-Nitrophenol
Chloroform	
Toluene	
1,1-Dichloromethane	
Metals	**Miscellaneous**
Chromium	Cyanide
Copper	
Lead	
Mercury	
Nickel	
Silver	
Zinc	

Table 3-11

HAZARDOUS NONPRIORITY POLLUTANTS DETECTED

Volatile Organics	Semivolatile Organics
Acetone	Alpha-Terpineol
	Benzoic acid
	o-Cresol
Pesticides and Herbicides	**Elements**
Dichloran	Aluminum
Etridazone	Barium
	Boron
	Manganese
	Molybdenum
	Titanium

TABLE 3-12
DATA SUMMARY FOR THE INDIRECT DISCHARGING HOSPITALS**

COMPOUND	RAW WASTEWATER DATA									METHOD A	METHOD B	METHOD C	NUMBER OF SAMPLES ANALYZED	NUMBER OF SAMPLES ABOVE DETECTION
	DATA SET #1	DATA SET #2	DATA SET #3	DATA SET #4	DATA SET #5	DATA SET #6	DATA SET #7	DATA SET #8	DATA SET #9	MEAN	MEAN	MEAN		
Volatile Organics (ug/l)														
Acetone	(50)	(50)	(50)	1,721	129	(50)	948	596	1,612	556	578	1,001	9	5
Benzene	(10)	91	104	(10)	(10)	(10)	(10)	(10)	(10)	22	29	98	9	2
Bromodichloromethane	(10)	(10)	(10)	(10)	(10)	(10)	38	(10)	(10)	4	13	38	9	1
Chloroform	(10)	(10)	(10)	(10)	(10)	24	17	13	(10)	6	13	18	9	3
Toluene	(10)	(10)	(10)	(10)	(10)	(10)	23	(10)	(10)	3	11	23	9	1
1,1-Dichloroethane	(10)	(10)	(10)	(10)	(10)	38	(10)	(10)	(10)	4	13	38	9	1
Subtotal										595	658	1,216		
Estimated Mass Discharge (lb/yr)**										565,555	625,766	1,155,755		
Semivolatile Organics (ug/l)														
Alpha-terpineol	(10)	174	169	(10)	(10)	(10)	(10)	(10)	(10)	38	46	172	9	2
Benzoic acid	789	(10)	(10)	(10)	(10)	(10)	(10)	(10)	(10)	88	97	789	9	1
Phenol	(10)	(10)	(10)	(10)	(10)	(10)	(10)	26	405	48	56	216	9	2
o-Cresol	(10)	(10)	(10)	(10)	(10)	11	(10)	(10)	(10)	1	10	11	9	1
4-Nitrophenol	(50)	(50)	(50)	(50)	(50)	(50)	83	(50)	(50)	9	54	83	9	1
Subtotal										184	262	1,270		
Estimated Mass Discharge (lb/yr)**										175,033	248,975	1,207,377		
Pesticides and Herbicides (ug/l)														
Dichloran	1.5	(50.0)	11.0	a	a	a	a	a	a	4.2	20.8	6.3	3	2
Etridazone	(50.0)	(50.0)	0.8	a	a	a	a	a	a	0.3	33.6	0.8	3	1
Subtotal										4.4	54.4	7.1		
Estimated Mass Discharge (lb/yr)**										4,215	51,749	6,702		

TABLE 3-12
DATA SUMMARY FOR THE INDIRECT DISCHARGING HOSPITALS**

COMPOUND	RAW WASTEWATER DATA									METHOD A	METHOD B	METHOD C	NUMBER OF SAMPLES ANALYZED	NUMBER OF SAMPLES ABOVE DETECTION
	DATA SET #1	DATA SET #2	DATA SET #3	DATA SET #4	DATA SET #5	DATA SET #6	DATA SET #7	DATA SET #8	DATA SET #9	MEAN	MEAN	MEAN		
Priority Pollutant Metals (ug/l)														
Chromium	(3)	(3)	(3)	140	9	139	(10)	(10)	30	35	39	80	9	4
Copper	62	58	72	120	82	105	75	(25)	28	67	70	75	9	8
Lead	(50)	(50)	(50)	91	(50)	(200)	(200)	(200)	(200)	10	121	91	9	1
Mercury	(0.2)	(0.2)	(0.2)	0.7	1.1	(0.2)	0.4	0.9	4.5	1	1	2	9	5
Nickel	(12)	(12)	(12)	13	(12)	(40)	(40)	42	(40)	6	25	28	9	2
Silver	2.7	13.0	7.6	75.0	12.0	89.0	31.0	8.0	140.0	42	42	42	9	9
Zinc	92	26	41	71	64	227	203	40	124	99	99	99	9	9
Subtotal										260	396	415		
Estimated Mass Discharge (lb/yr)**										247,168	376,335	394,982		
Priority Pollutant Misc. (ug/l)														
Cyanide, total	(20)	(20)	(20)	(20)	(20)	28	(20)	(20)	(20)	3	21	28	9	1
Subtotal										3	21	28		
Estimated Mass Discharge (lb/yr)**										2,958	19,859	26,619		
Common Ions (ug/l)														
Calcium	48,800	76,000	90,000	8,400	7,900	16,000	16,200	19,400	204,000	54,078	54,078	54,078	9	9
Iron	130	34	170	390	470	3,080	1,190	(50)	672	682	687	767	9	8
Magnesium	4,900	7,800	9,200	1,100	980	3,710	2,560	3,150	3,000	4,044	4,044	4,044	9	9
Sodium	100,000	210,000	240,000	12,000	11,000	88,200	80,200	27,200	38,600	89,689	89,689	89,689	9	9
Subtotal										148,493	148,498	148,578		
Estimated Mass Discharge (lb/yr)**										141,170,844,747	141,176,126,364	141,251,864,742		
Elements (ug/l)														
Aluminum	110	110	170	90	180	1,670	1,320	(100)	(100)	383	406	493	9	7
Barium	140	65	400	26	41	1,680	369	69	99	321	321	321	9	9
Boron	48	69	59	55	35	307	182	134	(100)	99	110	111	9	8
Manganese	2	4	4	12	10	184	24	(15)	19	29	30	32	9	8
Molybdenum	27	130	140	16	(10)	(100)	(100)	(100)	(100)	35	80	78	9	4
Titanium	10	20	20	19	21	(50)	(50)	(50)	(50)	10	32	18	9	5
Subtotal										877	979	1,054		
Estimated Mass Discharge (lb/yr)**										833,439	931,149	1,001,655		

TABLE 3-12
DATA SUMMARY FOR THE INDIRECT DISCHARGING HOSPITALS**

COMPOUND	RAW WASTEWATER DATA									METHOD A	METHOD B	METHOD C	NUMBER OF SAMPLES ANALYZED	NUMBER OF SAMPLES ABOVE DETECTION
	DATA SET #1	DATA SET #2	DATA SET #3	DATA SET #4	DATA SET #5	DATA SET #6	DATA SET #7	DATA SET #8	DATA SET #9	MEAN	MEAN	MEAN		
Conventionals (mg/l)														
BOD 5-day (carbonaceous)	76	23	58	65	63	340	200	100	130	117	117	117	9	9
Oil & grease, total recoverable	7.5	10.0	12.0	12.0	15.0	99.0	32.0	9.5	24.0	25	25	25	9	9
TSS	48	18	99	43	27	280	620	93	75	145	145	145	9	9
Subtotal										286	286	286		
Estimated Mass Discharge (lb/yr)**										272,215	272,215	272,215		

** = Mass discharge estimates based on 365 working days per year, 242 gallons of wastewater generated per bed, and 1,290,521 total beds in the indirect discharging hospitals.
(XX) = Indicates pollutant concentration in parentheses is less than the detection limit.
Method A = Using results in parentheses as if they were equal to zero.
Method B = Using all data, including the absolute values of the results in parentheses.
Method C = Using only the results that were above the detection limit.
- = Not Analyzed.

C) was an average of the detected pollutant concentration excluding the ND values (or the detection limit).

Three estimated mass loading values were also calculated for each pollutant group. In each method, the pollutant concentration averages were summed by compound group. The pollutant concentration sums were multiplied by the number of operating days per year (365), the gallons of wastewater generated per bed (242), and the total number of beds in the indirect discharging hospital industry (1,290,521), as well as a conversion factor to pounds discharged per year. The second and third values for mass loading were calculated in the same manner, except for using Method B and Method C averages, respectively.

For each pollutant, the percent detected above detection limit is presented instead of a percent occurrence. This approach eliminated counting an ND value as an occurrence.

Table 3-13 summarizes the hospital industry mass loadings by compound group, based on data from the four indirect discharging hospitals sampled during this study.

3.6.6 DISCUSSION

EPA's hospitals sampling effort included one community and three research and teaching hospitals having an average of 330 beds. As discussed in Section 2, there 215 direct and 6,662 indirect discharging hospitals in the United States. The Agency sampling effort was not an attempt to characterize hospital wastewater discharges in the United States. Such an effort would have required that the Agency sample a much larger number of hospitals of varying types an sizes. The purposes of EPA's efforts were to confirm what is known about hospital operations and their propensity for generating toxic and hazardous pollutants and to determine if additional study is warranted. EPA's rationale was essentially that if either expected pollutants were found at higher than expected levels or at treatable levels or that unexpected pollutants were found at a detectable levels, the Agency would conduct additional sampling and study efforts which might include sending a survey questionnaire to a sampling of U.S. hospitals.

In summary, the sampling results confirm what is known about wastewater generating operations within hospitals. Essentially no unexpected pollutants were found despite the fact that the Agency analyzed samples for over 400 toxic and hazardous (ITD listed) pollutants. The pollutants detected were found at low levels well below the wastewater treatability levels established for these pollutants. Consequently, the Agency does not believe that further study of the hospitals category is warranted. A complete discussion of all of the pollutant observations from the four hospital study is presented below.

TABLE 3-13

HOSPITAL INDIRECT DISCHARGING MASS LOADING SUMMARY

Compound Group	Method A* Total	Method B* Total	Method C* Total
Volatile Organics	83.7	91.9	169.7
Semivolatile Organics	25.7	36.6	177.3
Pesticides and Herbicides	0.6	7.6	1.0
Priority Pollutant Metals	36.3	55.3	58.0
Cyanide, total	0.4	2.9	3.9
Elements	122.4	136.8	147.1
Conventionals	40.0	40.0	40.0
MASS LOADING Subtotal**	308.4	371.1	597.0
Common Ions Total	20,700,000	20,700,000	20,700,000
MASS LOADING GRAND TOTAL	20,700,308	20,700,371	20,700,597

* Units are lb/yr per indirect discharging hospital
** Excluding Common Ions

The pollutants and associated levels detected in the wastewater of the four indirect discharging hospitals are for the most part typical of nonindustrial wastewater. However, some pollutants were detected at levels above those expected for nonindustrial wastewater. These pollutants were silver, barium, mercury, phenols, and acetone. In addition, some toxic volatile organics (solvents) were detected in a few samples. Finally, alpha-terpineol and benzoic acid were detected in a few samples. The sources of silver and barium in hospital wastewater are the x-ray and other diagnostic operations conducted at all hospitals while the detectable concentrations of mercury probably result from the disposing of chemical solutions containing mercury. Phenols are used as disinfecting agents in operating room and other area cleanup operations. Acetone is commonly used in hospital laboratories to clean glassware. Various solvents such as chloroform, benzene or 1,2-dichloroethane may be used in various research and other laboratories in the course of routine bench level analytical procedures. Alpha-terpineol has been detected in the wastewater of other categories but the source of this pollutants has not yet been established. The sampling results for each of above pollutants or groups of pollutants is discussed in following paragraphs.

Silver

The average concentration of silver discharged from the one hospital which had an in-house silver recovery system was 7.8 ug/l (three data points) while the average concentration of silver discharged from the three hospitals which did not have in- house silver recovery systems was 69.4 ug/l (five data points). The former concentration is below the average silver concentration found in the influents of POTWs receiving a less than ten percent contribution of industrial wastewater (10 ug/l). The latter effluent concentration is well below the precipitation/clarification treatability level (about 1000 ug/l) for silver. An average indirect hospital with 192 beds would be expected to discharge 0.01 lbs per day of silver to its POTW assuming it did not have a silver recovery system in-place, and 0.09 lbs per day of silver if it did. The total discharge of silver from all indirect hospitals is estimated to be 600 lbs per day assuming no silver recovery systems are in-place and 67 lbs per day assuming all indirect hospitals have silver recovery systems in-place.

EPA projects that the average direct discharger hospital with activated sludge or aerated lagoon type of biological treatment in-place would remove up to 96 percent of the silver generated by its x-ray and photographic development operations (see the EPA treatability manual, Vol.III section 3.2.1) Although many hospitals have trickling filters rather than activated sludge or aerated lagoon systems, and data on silver removal by trickling filters is not available, EPA expects that silver removal by trickling filters would be similar to that exhibited by activated

and aerated lagoon systems since the primary removal mechanism, adsorption onto biomass, should also be operative for trickling filters as well.

In summary, neither the amount of silver discharged by individual hospitals (direct or indirect) with or without silver recovery nor the total amount of silver expected to be discharged by direct and indirect hospitals is significant. Therefore, the Agency is not considering technology based national regulations for silver.

Phenols Phenol was detected twice in the raw waste of one hospital at an average concentration of 216 ug/l. In addition, 4-nitrophenol was found once in the raw waste of another hospital at a concentration of 83 ug/l, and o-cresol was detected once in the raw waste of one hospital at a concentration of 11 ug/l. All three pollutants appear to be readily biodegradable (see EPA Treatability Manual, Vol. III sections 3.2.1 and 3.2.2) and, as a result, similar concentrations in the influent of hospitals with biological treatment should be reduced to nondetect levels and would result in de minimus discharges of these pollutants to the nation's surface waters from direct discharging hospitals. Neither the concentration levels nor the frequency of occurrence of phenol and 4-nitrophenol suggest that their discharge by the hospitals category would cause pass-through or interference problems at the nation's POTWs. Consequently, the Agency does not believe that controls on the discharge of these pollutants are warranted.

Barium

Barium was detected in all eight raw waste samples taken at all four sampled hospitals at an average concentration of 321 ug/l. The average concentration of barium detected in the influents of nonindustrial POTWs (see Table 3-13) was 138 ug/l. While the Agency expects barium to be found in the wastewater of the vast majority of hospital dischargers, direct and indirect, the concentration levels are not expected to be significant. Only one sample showed barium at a concentration higher than 1 ppm (1620 ug/l)). Generally, barium concentrations in the wastewater of a given hospital will vary depending on the number of diagnostic procedures being conducted.

The Agency expects that the barium concentration in the raw wastewater of direct discharger hospitals will be reduced greatly as the result of adsorption onto the biomass in the biological systems in-place. Similarly, the barium that hospitals discharge to POTWs will accumulate in POTW sludges. Assuming all of the barium discharged by the average direct hospital accumulates in the average POTWs sludge, then the average hospital will contribute 0.12 lb/day of barium to its POTW's sludge. This amount should not cause sludge disposal problems.

Acetone

Acetone, a hazardous nonpriority pollutant was detected in the raw waste of three hospitals in five of six samples at an average concentration of 1,001 ug/l. Acetone is a water soluble, extremely volatile, but biodegradable pollutant and, as a result, should be both volatilized and biodegraded to a considerable extent in the biological systems of direct dischargers such that discharges of acetone to the nation's surface waters from hospital should be de minimus and not of concern. While the projected daily discharge of acetone from the nation's 6,667 hospitals is projected to be about 2573 lbs/day based on an average discharge concentration of 1 ppm, this acetone loading is not significant because the total discharge would be spread out evenly among the nation's POTWs such that the average daily loading of acetone is about 0.5 lbs per POTW. The Agency does expect small amounts of air emissions of acetone at POTWs without secondary treatment which receive hospital wastes, however. Nonetheless, the Agency does not believe that the projected loadings of acetone from hospitals will cause either pass through or interference problems at the nations' POTWs.

Mercury was detected in four of eight samples in the raw wastewater of three hospitals at an average concentration of 1.5 ug/l or only slightly above influent. The average concentration of mercury observed at nonindustrial POTWs which is 0.6 ug/l. This average level is significantly below any categorical average and well below any reasonable wastewater treatability level (See EPA Treatability Manual, Vol.III sections 3.1.1 through 3.1.5). As a result, mercury discharges from hospitals are not of concern.

Other Pollutants Detected

In addition to the above pollutants, various other organic pollutants were detected at least once albeit at low concentrations in the raw wastewater of hospitals. Chloroform was detected in three samples at two hospitals at an average concentration of 18 ug/l. Benzene was found in two samples collected at one hospital at an average concentration of 98 ug/l. Toluene and bromodichloromethane were found in one sample at one hospital at concentrations of 23 and 38 ug/l, respectively. In addition to these observations, certain other low level concentrations of alpha-terpineol and benzoic acid were found in samples of hospital wastewater. However, the analytical veracity of these observations is suspect.

SECTION 4.0

TREATMENT AND DISPOSAL METHODOLOGIES

4.1 CHEMICAL WASTE

Chemical wastes generated by hospitals, especially those associated with research, represent a wide variety of compounds and associated hazards. Most chemical waste is generated in clinical and research laboratories. Nonhazardous chemical wastes can be contained and disposed of by landfill, incineration, or sewering. Hazardous chemical wastes must be properly contained and disposed of in accordance with federal, state, and local regulations.

Hazardous chemical waste is disposed of in different ways, depending on the nature of the material. All hazardous waste must be properly segregated, packaged, and labeled. Amounts must be documented relative to destination, disposal method, and responsible person. Some hospitals hire outside contractors to handle all hazardous chemical waste disposal operations. Larger hospitals may have staff specifically designated to pick up, properly document, and package the hazardous waste before shipping it to an approved disposal site.

Figure 4-1 illustrates a typical route for handling chemical hazardous wastes in hospitals.

4.2 RADIOACTIVE WASTE

Users of radioisotopes must treat and dispose of the residual waste product. Radioactive waste disposal options include separation and confinement, dilution and dispersion, incineration, and landfill.

4.2.1 SEPARATION AND CONFINEMENT

Materials containing short-lived radioactive waste (i.e., waste with half-lives of 60 days or less) are separated from materials with longer half-lives, and stored for decay up to ten half-lives in a secure area (St. Germain, 1986). This permits the radioactivity to decrease and approach naturally occurring background levels. Table 4-1 lists the half-lives for the most common radioisotopes currently used in nuclear medicine. After the radioactivity has decreased to near background level, the residual radioactive material must be disposed of in some fashion, unless it exhibits other hazardous characteristics that preclude its disposal as strictly radioactive (ASHE, 1985). Disposal methods are dictated by the state of the material (i.e., gas, liquid, or solid). disposal of radioactive gases can be accomplished by means of a dedicated exhaust system or an activated charcoal trap. When these devices are used, it is important that they are properly maintained and that any off- gases are monitored. Radioactive liquids are often disposed in a particular sink designated for low-level radioactive wastes.

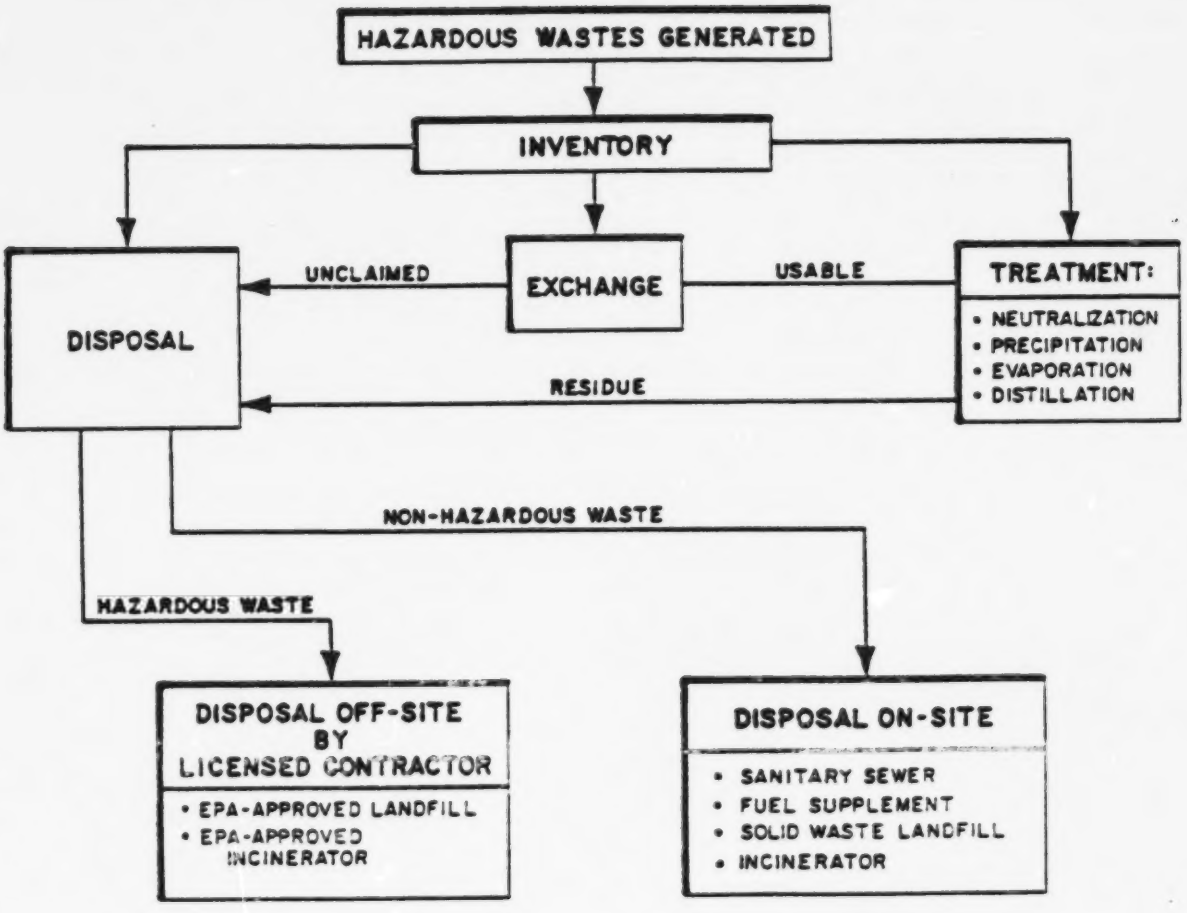

HAZARDOUS WASTES GENERATED
INVENTORY
DISPOSAL
UNCLAIMED
EXCHANGE
USABLE
TREATMENT:
• NEUTRALIZATION
• PRECIPITATION
• EVAPORATION
• DISTILLATION
RESIDUE
NON-HAZARDOUS WASTE
HAZARDOUS WASTE
DISPOSAL OFF-SITE BY LICENSED CONTRACTOR
• EPA-APPROVED LANDFILL
• EPA-APPROVED INCINERATOR
DISPOSAL ON-SITE
• SANITARY SEWER
• FUEL SUPPLEMENT
• SOLID WASTE LANDFILL
• INCINERATOR

TABLE 4-1

RADIOISOTOPIC HALF-LIVES

RADIOISOTOPE	HALF-LIFE (DAYS)*
H^{3}	4.5×10^{3}
C^{14}	2×10^{6}
P^{32}	1.43×10^{1}
S^{35}	8.71×10^{1}
Ca^{45}	1.65×10^{2}
Cr^{51}	2.78×10^{1}
Co^{57}	2.7×10^{2}
Co^{60}	1.9×10^{3}
Ga^{67}	3.25×10^{0}
Mo^{99}	2.78×10^{0}
Tc^{99m}	2.5×10^{-1}
In^{111}	2.81×10^{0}
I^{123}	5.54×10^{-1}
I^{125}	6×10^{1}
I^{131}	8×10^{0}
Xe^{133}	5.27×10^{0}
Yb^{169}	3.2×10^{1}
Tl^{201}	3.04×10^{0}

* Source: Robert C. Weast, Editor. CRC Handbook of Chemistry and Physics; 63RD Edition; CRC Press, Inc.; Boca Raton, Florida; pp. B-256-339; 1982.Table 4-1

Restricting the quantity of radioactive materials and handling of these fluids are important standard operating procedures (ASHE, 1985). The most widely practiced waste management technique for radioactive solids is storing for decay and then packaging for disposal for disposal at a designated land-burial site in a remote location with controlled access (Hendee, 1986).

To ensure the safety and integrity of the on-site decay area and storage process, it is essential that radioactive substances be monitored and controlled at all times. These monitoring procedures should be recorded and should reflect the results of periodic surveys of the hospital storage area.

4.2.2 DILUTION AND DISPERSION

Dilution and dispersion techniques are appropriate for most liquids and gaseous radioactive hospital wastes. Allowable discharge concentrations to the sanitary sewer and air are given in the maximum permissible concentration (MPC) tables of Chapter 10 of the Code of Federal Regulations (CFR) Part 20 (see Appendix B). The regulations allow for an average of the discharge concentrations over a specific time period; many institutions have chosen to discharge at the MPC to avoid any questions about the concentration at any point beyond the institution's control. In essentially all regions, measurements must be taken at exit points to verify these calculations (St. Germain, 1986).

Some institutions choose not to discharge radioactive materials into the sanitary sewer, except for patient excreta, which is currently exempt from regulation as radioactive waste. However, some institutions store the urine from patients who had been given large amounts of Iodine-131 before discharging it to the sanitary sewer (St. Germain, 1986).

The objective of these waste disposal techniques is to reduce concentrations of radioactive materials to background levels before they enter the sanitary sewer system or are discharged into the atmosphere (ASHE, 1985).

4.3 INFECTIOUS WASTE

The disposal of infectious waste currently is not federally regulated. Recommended disposal methods have been developed by the EPA, CDC, and JCAH (see Table 3-5) (ASHE, 1985). The most common method of treatment and disposal is steam sterilization, followed by incineration and landfill disposal and sewering for certain liquids.

4.3.1 STEAM STERILIZATION

Steam sterilization is used to treat infectious waste and render it noninfectious by killing any pathogens present in the waste material. Before being placed in the steam sterilizer, waste is

contained in plastic bags (usually double-bagged) and put in a rigid container to prevent spillage.

The equipment used for steam sterilization is known as a steam sterilizer or autoclave. A pressure vessel, called a "retort," has also been marketed recently for the steam sterilization of infectious waste. There are tow general types of steam sterilizers: (1) the gravity displacement type, in which the displaced air flows out the drain through a steam-activated exhaust valve, and (2) the pre-vacuum type, in which a vacuum is imposed to remove the air before steam is introduced into the chamber. With both types, the temperatures of the treatment chamber and the waste load increase as air is replaced with pressurized steam. When all air is removed and replaced with steam, the saturated steam, essential for accomplishing sterilization, is present within the treatment chamber.

The operating temperature of the steam sterilizer is a function of the steam pressure. Most gravity-displacement steam sterilizers operate at 121°C (250°F) with saturated steam at 17 to 18 pounds per square inch gauge (psig) within the chamber, although some units operate at 132°C (270°F) with saturated steam at 27 to 32 psig. A typical retort operates at 132°C to 135°C (270 to 275°F) with chamber pressure at 35 to 38 psig.

The criteria used to set minimum exposure time for steam sterilization are the kill times for Bacillus stearothermophilus spores exposed to wet head (e.g., 15 minutes at 121°C [250°F]). Kill times at various temperatures are listed in Table 4-2. In practice, to provide an adequate margin of safety, exposure times are usually at least double the kill times (Perkins, 1969). With steam sterilization of infectious wastes, it is essential to ensure that the entire waste load has been exposed to the necessary temperature for the required period of time. Heating the containers and the waste usually lags behind heating the chamber (Perkins, 1969). With steam sterilization of infectious wastes, it is essential to ensure that the entire waste load has been exposed to the necessary temperature for the required period of time. Heating the containers and the waste usually lags behind heating the chamber (Perkins, 1969; and Rubbo and Gardner, 1965).

There have been reports that the commonly used (and even prolonged) treatment times are often not sufficient to sterilize wastes because the center of the waste load does not reach the required temperature. One method of ascertaining when the interior of a load has attained the proper temperature is to use thermocouples. However, thermocouples are not standard equipment for steam sterilizers. It is important, therefore, that the principles of steam sterilization be understood and used in the development of standard operating procedures. Following the sterilization procedure, the waste is sent to a sanitary landfill for disposal.

TABLE 4-2

STEAM STERILIZATION

Temperature		Spore Kill Time
(°F)	(°C)	Minutes
48	116	30
245	118	18
250	121	12
257	125	8
270	132	2
280	138	0.8

Source: E. Hanel, Jr., Chemical Disinfection in Control of Biohazards in the Research Laboratory, Course Manual; Table 1A; John Hopkins University, School of Hygiene and Public Health; Baltimore, Maryland; 1981

4.3.2 Incineration

With incineration, the waste is combusted, producing gases and residue or ash. The product gases are vented to the atmosphere through the incinerator stack, while the residue from incineration of infectious waste is disposed of in a sanitary landfill. The advantage of incineration is that it greatly reduces the mass and volume of the waste (often by more than 95 percent) which, in turn, substantially reduces transport and disposal costs.

An incinerator may either be located on-site at the hospital where the infectious waste is generated or at some off-site location. Any incinerator can be used to treat infectious waste if it does so properly by killing the pathogens and destroying any biologically active material.

Traditionally, pathological incinerators have been used to incinerate pathological waste, as well as other types of infectious waste. Most pathological incinerators are multi- chambered with relatively small capacities; they provide high combustion temperatures and can be operated intermittently. Because of their design and operating characteristics, pathological incinerators are appropriate for the incineration of infectious waste when operated properly. The intermittent mode of operation is suitable for pathological and other types of infectious waste because a single facility seldom generates quantities large enough for a continuous-feed incinerator. Most large hospitals and medical centers have pathological incinerators on the premises; they can often be found in smaller hospitals, as well as large research facilities.

A rotary kiln is much larger than a pathological incinerator, and is therefore usually found in an industrial setting. A rotary kiln provides a controlled environment which, coupled with its rotation, facilitates complete combustion of the waste. The rotary kiln is the traditional type of incinerator used to treat many types of hazardous waste. Rotary kilns are also being used in commercial incineration operations to treat various infectious wastes.
In recent years, there has been interest in total incineration of all waste generated by a facility, with utilization of energy recovered from the combustion process. If total incineration is undertaken at a facility that generates infectious waste, the possibility of including the infectious waste in the feed should be evaluated carefully. Management problems may be associated with the special handling of infectious waste. For example, infectious waste should be a separate wastestream that is not mixed with other wastes, and it should be incinerated promptly. In addition, special techniques (e.g., in feeding) might be required to ensure proper combustion of the infectious waste to eliminate biological hazards.

The most important factor in incineration is that the burn temperature be 1,800°F for a period of one second. Because a large

amount of infectious waste consists of plastics and moist materials, the combustion process may be interrupted with the addition of these materials; the temperature in the incinerator tends to decrease. If this occurs, the infectious material will not be incinerated properly and pathogens may still be alive in the ash or effluent from the stack. Therefore, it is important to establish standard operating procedures and monitor performance on a regular basis to ensure proper incineration.

4.3.3 Liquid Disposal in Sewer

Disposal of liquid infectious waste in sewers is not recommended by EPA (see Table 3-5); however, no federal regulations prohibit this type of disposal. If no local or state regulations address this action, it is likely that hospitals will dispose infectious liquids in sewers after holding and disinfection. The most common liquid infectious materials are blood and blood-related products, as well as excretion from infected patients or animals.

4.4 PHYSICALLY HAZARDOUS WASTE

Sharps present the double hazards of disease transmission and physical injury. Most hospitals have established programs to reduce the likelihood of punctures due to sharps. Sharps are usually placed in rigid, puncture-proof containers at the site of origin. The containers may then be steam-sterilized to prevent disease transmission. After sterilization, the containers may be incinerated or landfilled. Many states, however, have regulations requiring the destruction of needles and syringes to prevent reuse. All needles and syringes should be rendered non- usable before disposal by incineration or in a landfill; this can be achieved by grinding or compacting after treatment.

Pressurized vessels (e.g., aerosol cans and gas tanks) may present a physical hazard and must be handled properly. Most hospitals keep track of gas tanks, and dispose or recycle them through the gas supplier. Aerosol cans are usually disposed in landfalls; however, some may be incinerated, which could result in explosions and damage to the incinerator. Therefore, most hospitals attempt to segregate pressurized vessels from the wastestream to prevent damage to incinerators and personnel.

4.5 WASTEWATER

4.5.1 Pretreatment Technologies

Hospitals use segregation and pretreatment for economic reasons. The most frequently used in-house pollution control measures include silver recovery, solvent recycling and reclamation, and implementation of a plan that ensures proper collection and disposal of hazardous substances according to RCRA.

4.5.1.1 Silver Recovery

Silver recovery is used by x-ray departments to recover silver from the spent fixer solution produced when developing x-ray film. Only about one-third of the silver remains on the film to form an image; the balance is washed into the fixer solution (ASHE, 1980). Although the primary reason for silver recovery is an economic one, local water quality regulations may require hospitals to reduce concentrations of silver in their wastewater. Metallic replacement and electrolytic plating are the most common methods used to recover silver.

Silver recovery by metallic replacement involves a chemical process to obtain silver from the spent fixer solution. The spent fixer solution is brought into contact with a more chemically active metal, such as iron. The reaction results in the more active metal going into solution and the silver precipitating out for recovery (ASHE, 1980). Cartridges containing the more active metal are installed in or near the x-ray department. The spent fixer solution flows through the inlet of the cartridge, and comes in contact with the metal. The fixer solution then flows out of the cartridge to a drain. The silver precipitate is collected and sold. This method can recover 95 percent or more of the available silver. Efficiency decreases significantly when the cartridge is near exhaustion or used infrequently. A summary of the advantages and disadvantages of this methodology compared to other silver recovery systems follows (ASHE, 1980).

Advantages

- Low initial cost
- Ease of installation and disconnection
- No energy requirement
- Low maintenance
- High theoretical recovery efficiency
- Usable with wash water

Disadvantages

- Units must be replaced every 90 days; therefore, lifetime costs are high.
- Careful monitoring is required to avoid exhaustion, plugging, or channeling.
- Shipping and refining costs are high.
- The possible dollar return may be low because of the high costs.
- Spent fixer solution cannot be reused.

Silver recovery by electrolytic plating uses an electrical charge to obtain the silver. A controlled direct electrical current is passed between two electrodes, charging one positively (anode) and one negatively (cathode). Because the silver ions in the spent fixer solution carry a positive charge, they are attracted to the stainless steel cathode and build up into a layer. Silver is plated on the cathode at a rate determined by the recovery current

(8 amps = 1 troy ounce in 1 hour) (ASHE, 1980).

A summary of the advantages and disadvantages of this methodology compared to other silver recovery systems follows (ASHE, 1980).

Advantages

- High purity of silver
- Low shipping and refining costs
- Extended life of equipment
- Reusable fixer solution in recirculating systems
- Constant efficiency of operating properly

Disadvantages

- Higher capital expenditure*
- Increased maintenance and downtime because of complexity*
- Lower theoretical efficiency*
- More complex installation*
- Electrical energy required

* As compared to metallic replacement only

4.5.1.2 Solvent Recycling and Reclamation

Hospitals use many different types of solvents throughout the facility. Any solvent remaining after use (i.e., spent solvent) is considered a hazardous waste. Because of federal regulations, these solvents must be tracked from "cradle to grave" to ensure proper disposal of hazardous waste materials. To accomplish this, many hospitals have established collection programs to contain these hazardous wastes for documentation and disposal.

Some hospitals use large quantities of specific solvents (e.g., alcohols, xylenes) that can be reclaimed after use. Reclamation or recycling of spent solvents, often by an outside contractor, reduces the amount of hazardous waste produced and the solvent to be purchased.

Reclamation can also be performed "in-house" if enough solvent is recycled to render the purchase of equipment economically feasible. In-house reclamation is accomplished by distillation of the spent solvent. Most hospitals use this technology to reclaim xylene and ethanol.

Xylene and ethanol are used primarily in the histology laboratories to prepare tissues and slides. During this preparation, the solvent becomes contaminated with various dyes. The spent xylene or ethanol can be distilled, which provides a relatively pure (i.e., 90 to 95 percent) solvent that can be reused. The remaining amount of contaminated solvent must be contained and disposed of as a hazardous waste.

Most hospitals have a plan designed to meet RCRA regulations to collect and package hazardous wastes before transport to a disposal site. These plans require documentation of the type and amount of hazardous waste produced and a system for tracking these wastes to the final disposal site. The hospitals are responsible for the proper packaging, transporting, and disposing of their hazardous waste. Most hospitals hire a contractor to transport and dispose of the waste, who documents the disposal locations for the hospital's records.

4.5.2 Biological Treatment

Most hospitals are located in areas of high population density and 97 percent discharge to municipal treatment systems. However, approximately 215 hospitals treat their own wastewater and are direct dischargers. The most common biological wastewater treatment system for these hospitals is the trickling filter; other systems include activated sludge and aerated lagoons.

4.5.2.1 Trickling Filters

A trickling filter is a biological waste treatment process in which a fixed microbial population is used to biodegrade the organic components of wastewater. The physical unit consists of a suitable structure packed with an inert medium (usually rock, wood, or plastic) on which a biological mass is grown. The wastewater is distributed over the upper surface of the medium; as it flows through the medium covered with biological slime, both dissolved and suspended organic matter are removed by adsorption. The adsorbed matter is oxidized by the organisms in the slime during their metabolic processes. Air flows through the filter by convection, thereby providing the oxygen needed to maintain aerobic conditions.

As the microorganisms grow, the thickness of the slime layer increases. Periodically, the slime breaks off the medium and is replaced with new growth. This phenomenon of losing the slime layer, called sloughing, is primarily a function of the organic and hydraulic loadings on the filter. The effluent from the filter is usually passed to a clarifier to settle and remove the agglomerated solids.

Wastewater is applied to the filter by either a fixed-spray nozzle system or a rotating distribution system. Fixed-spray nozzles are used less frequently than rotary distributors because the latter have greater reliability and ease of maintenance. The rotary units consist of two or more distributor arms mounted on a pivot in the center of the filter. As a result of the dynamic action of the incoming wastestream, the arms rotate and the nozzles distribute the wastewater. Most filter processes incorporate recirculation of the treated effluent to provide uniform hydraulic loading and dilute high-strength wastewater.

The main advantages of trickling filters are simplicity, low power and operating costs, and ease of operation and maintenance. In addition, because of its inherent stability, a trickling filter is not easily upset by shock loads or sudden variations in influent volume.

Limitations include vulnerability to climatic changes and low temperatures. Recirculation may be restricted during cold weather as a result of cooling effects; flies and odors are common problems; and wastewater containing high concentrations of soluble organics is less effectively treated. Also, trickling filters have limited flexibility and control compared to other processes.

4.5.2.2 Activated Sludge

The activated sludge process is a biological treatment used primarily to remove organic material from wastewater. This process is characterized by the suspension of aerobic and facilitative microorganisms, maintained in a relatively homogeneous state by either mixing or the turbulence induced by aeration. These microorganisms oxidize soluble organics and agglomerate colloidal and particulate solids in the presence of dissolved molecular oxygen. If needed, the process can be preceded by sedimentation to remove larger and heavier solid particles. The mixture of microorganisms, agglomerated particles, and wastewater (referred to as mixed liquor) is aerated in an aeration basin. The aeration step is followed by sedimentation to separate biological sludge from treated wastewater. The major portion of the microorganisms and solids removed by sedimentation is recycled to the aeration basin to be recombined with incoming wastewater. The excess, which constitutes the waste sludge, is sent to sludge disposal facilities.

The activated sludge biomass consists of bacteria, fungi, protozoa, rotifers, and other higher forms of life. The bacteria comprise the most important group of microorganisms because they are responsible for stabilization of the organic matter and formation of the biological floc. The function of the biomass is to convert soluble organic compounds to cellular material. This conversion consists of transfer of organic matter (also referred to as substrate or food) through the cell wall into the cytoplasm, oxidation of substrate to produce energy, and synthesis of protein and other cellular components form the substrate. Some of the cellular material undergoes auto-oxidation (i.e., self-oxidation or endogenous respiration) in the aeration basin; the remainder forms new growth or excess sludge. In addition to the direct removal of dissolved organics by biosorption, the biomass can also remove suspended and colloidal matter. The suspended matter is removed by enmeshment in the biological floc. The colloidal material is removed by physiochemical adsorption on the biological floc. Volatile compounds may be driven off, to a certain extent, in the aeration process. Metals are also partially removed, and accumulate in the sludge.

The effectiveness of the activated sludge process is governed by several design and operation variables, including organic loading, sludge retention time, hydraulic or aeration detention time, and oxygen requirements. The organic loading is described as the food-to-microorganism (F/M) ratio; that is, the kilograms of BOD_5 applied daily to the system per kilogram of mixed liquor suspended solids (MLSS). The MLSS in the aeration tank is determined by the rate and concentration of activated sludge returned to the tank. The organic loading (F/M ratio) affects the BOD removal, oxygen requirements, biomass production, and the settleability of the biomass. The sludge retention time (SRT) or sludge age is a measure of the average retention time of solids in the activated sludge system.

SRT is important in the operation of an activated sludge system because it must be maintained at a level greater than the maximum generation time of microorganisms in the system. If adequate SRT is not maintained, the bacteria are washed from the system faster than they can reproduce themselves, and the process fails. The SRT also affects the degree of treatment and production of waste sludge. A high SRT results in carrying a greater quantity of solids in the system and obtaining a higher degree of treatment, as well as the production of less waste sludge. A hydraulic detention time is used to determine the size of the aeration tank using the F/M ratio, SRT, and MLSS.

Oxygen requirements are based on the amounts required for both BOD_5 synthesis and endogenous respiration. The design parameters, usually determined in a treatability study, will vary with the type of wastewater to be treated. The oxygen requirement to satisfy BOD synthesis is established by the wastewater characteristics. The oxygen requirement to satisfy endogenous respiration is established by the total solids maintained in the system and their characteristics.

Compared to other methods discussed herein, the conventional activated sludge process provides a higher quality effluent. It has a limited organic loading capacity and can be upset with extreme variations in hydraulic, organic, or toxic loadings. Other disadvantages are high operating costs, operational complexity, and energy consumption.

4.5.2.3 Aerated Lagoons

A body of wastewater contained in an earthen dike and designed for biological treatment is termed a "lagoon" or "stabilization pond." Another often-used synonym is "oxidation pond." While in the lagoon, wastewater is biologically treated to reduce degradable organics and suspended solids by sedimentation. The biological process occurring in the lagoon can be either aerobic or anaerobic, depending on the type of lagoon. Because of their low construction and operating costs, lagoons offer a financial advantage over other treatment methods; for this reason, they have become popular where

sufficient land is available at reasonable cost.

The many different types of lagoons can be grouped into four major classes, based on the nature of biological activity.

Aerobic Algae Lagoons

Aerobic algae lagoons are shallow ponds that contain dissolved oxygen (DO) throughout their liquid volume at all times (i.e., there are no anaerobic zones). Aerobic bacterial oxidation and algal photosynthesis are the principal biological processes involved. Aerobic lagoons are best suited to treating soluble organics in wastewater relatively free of suspended solids. Thus, they are often used to provide additional treatment of effluents from anaerobic ponds and other partial treatment processes.

Anaerobic Lagoons

Anaerobic lagoons are relatively deep ponds (up to 20 feet) with steep sidewalls. Anaerobic conditions are maintained by keeping organic loading so high that complete deoxygenation is prevalent. Some oxygenation is possible in a shallow surface zone. If floating materials in the waste form an impervious surface layer, complete anaerobic conditions will develop. Treatment or stabilization results from anaerobic digestion of organic waste by acid-forming bacteria that break down organics. The resultant acids are then converted to carbon dioxide, methane, and other end products. Anaerobic lagoons are capable of providing treatment of high-strength wastewater and are resistant to shock loads.

In a typical anaerobic lagoon, raw wastewater enters near the bottom of the pond (often at the center) and mixes with the active microbial mass in the sludge blanket, which can be up to two meters (six feet) deep. The discharge is located near a side of the pond, submerged below the liquid surface. Excess sludge is washed out with the effluent; recirculation of waste sludge is not required.

Facultative Lagoons

Facultative lagoons are intermediate depth ponds (i.e., three to eight feet) in which wastewater is stratified into three zones: an anaerobic bottom layer, an aerobic surface layer, and an intermediate zone. Stratification is a result of solids settling, and temperature and water density variations. Oxygen in the surface stabilization zone is provided by aeration and photosynthesis. The photosynthetic activity at the lagoon surface produces oxygen diurnally; that is, increasing the dissolved oxygen content during daylight and decreasing it at night. In general, the aerobic surface layer serves to reduce odors while providing treatment of soluble organic by-products of the anaerobic processes operating at the bottom. Sludge at the bottom of facultative lagoons will undergo anaerobic digestion producing carbon dioxide and methane.

Aerated Lagoons

Aerated lagoons are medium depth basins (i.e., 8 to 15 feet) in which oxygenation is accomplished by mechanical or diffused aeration units and from induces surface aeration. Surface aerators may be either high-speed, small-diameter, or low-speed, large-diameter impeller devices, either fixed-mounted on piers or float-mounted on pontoons. Diffused aerators may be plastic pipe with regularly spaced holes, static mixers, helical diffusers, or other types. Aerated lagoons can be either aerobic or facultative. Aerobic ponds are designed to maintain complete mixing. Thus, all solids are in suspension; separate sludge settling and disposal facilities are required to separate the solids from the treated wastewater.

The major advantages of treatment lagoons are that they (1) can handle considerable variations in organic and hydraulic loading with little adverse effect on effluent quality; (2) require minimum

control and thus can be operated by relatively unskilled operators; (3) have low operation and maintenance costs. The major limitations are (1) the large land area required; (2) localized odor problems that may occur when conditions become anaerobic (more difficult to prevent if icing occurs); (3) excessive accumulation of algal and bacterial cells in the effluent, which creates a significant BOD and suspended solids load in the receiving water; and (4) the performance of the process is temperature-dependent and effluent quality will vary.

GLOSSARY OF ACRONYMS

AHA	American Hospital Association
ASHE	American Society for Hospital Engineering
BAT	Best Available Technology
BOD	Biochemical Oxygen Demand
BPT	Best Practicable Technology
CDC	Centers for Disease Control
CFR	Code of Federal Regulations
COD	Chemical Oxygen Demand
CWA	Clean Water Act
DO	Dissolved Oxygen
DSE	Domestic Sewage Exclusion
DSS	Domestic Sewage Study
EPA	U.S. Environmental Protection Agency
HSWA	Hazardous and Solid Waste Amendments
ITD	Industrial Technology Division
JCAH	Joint Commission on Accreditation of Hospitals
MLSS	Mixed Liquor Suspended Solids
MPC	Maximum Permissible Concentration
ND	Not Detected
NIH	National Institutes for Health
NRDC	Natural Resources Defense Council
NSPS	New Source Performance Standards
POTW	Publicly Owned Treatment Works
psig	pounds per square inch gauge
RCRA	Resource Conservation and Recovery Act
SRT	Sludge Retention Time
TOC	Total Organic Carbon
TSS	Total Suspended Solids

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APPENDIX A

ITD LIST OF ANALYTES

TABLE A-1

LIST OF ANALYTES MONITORED

Volatile Organic Compounds	Volatile Organic Compounds
1,1,1,2-Tetrachloroethane	Methyl ethyl ketone
1,1,1-Trichloroethane	Methyl iodide
1,1,2,2-Tetrachloroethane	Methyl methacrylate
1,1,2-Trichloroethane	Methylene chloride
1,1-Dichloroethane	N,N-dimethylformamide
1,1-Dichloroethene	Tetrachloroethene
1,2,3-Trichloropropane	Toluene
1,2-Dibromoethane	Trans-1,2-dichloroethene
1,2-Dichloroethane	Trans-1,3-dichloropropene
1,2-Dichloropropane	Trans-1,4-dichloro-2-butene
1,3-Dichloropropane	Trichloroethene
1,3-Dichloropropylene	Trichlorofluoromethane
1,3-Dichloro-2-propanol	Vinyl acetate
1,4-Dioxane	Vinyl chloride
1-Bromo-2-chlorobenzene	
1-Bromo-3-chlorobenzene	Semivolatile Organic Compounds
2-Butenal	
2-Chloroethyl vinyl ether	1,2,3-Trichlorobenzene
2-Hexanone	1,2,3-Trimethoxybenzene
2-Picoline	1,2,4,5-Tetrachlorobenzene
3-Chloropropene	1,2,4-Trichlorobenzene
4-Methyl-2-pentanone	1,2-Dichlorobenzene
Acetone	1,2-Diphenylhydrazine
Acrolein	1,3,5-Trithiane
Acrylonitrile	1,3-Dichlorobenzene
Allyl alcohol	1,3-Dichloro-2-propanol
Benzene	1,4-Dichlorobenzene
Bromoform	1,4-Dinitrobenzene
Bromodichloromethane	1,4-Naphthoquinone
Bromomethane	1-5-Naphthalenediamine
Carbon disulfide	1-Chloro-3-nitrobenzene
Carbon tetrachloride	1-Methylfluorene
Chlorobenzene	1-Methylphenanthrene
Chloroethane	1-Methylphenanthrene
Chloroform	1-Naphthylamine
Chloromethane	1-Phenylnaphthalene
Chloroprene	2,3,4,6-Tetrachlorophenol
Cis-1,3-dichloropropene	2,3,6-Trichlorophenol
Dibromochloromethane	2,3-Benzofluorene
Dibromochloropropane	2,3-Dichloroaniline
Dibromomethane	2,3-Dichloronitrobenzene
Dichlorofluoromethane	2,4,5-Trichlorophenol
Diethyl ether	2,4,5-Trimethylaniline
Dimethyl sulfone	2,4,6-Trichlorophenol
Ethyl benzene	2,4-Diaminotoluene
Ethyl cyanide	2,4-Dichlorophenol

Table A-1 (continued

Ethyl methacrylate	2,4-Dinitrophenol
Isobutyl alcohol	2,4-Dinitrotoluene
Methacrylonitrile	2,6-Di-tert-butyl-p-benzoquinone

Semivolatile Organic Compounds	Semivolatile Organic Compounds
2-Chloronaphthalene	Carbazole
2-Chlorophenol	Chloroacetonitrile
2-Isopropylnaphthalene	Chyrsene
2-Methylbenzothioazole	Dibenzothiophene
2-Methylnaphthalene	Dibenzo(a,h)anthracene
2-Naphthylamine	Dichloran
2-Nitroaniline	Diethyl phthalate
2-Nitrophenol	Dimethyl phthalate
2-Phenylnaphthalene	Dinitrocresol
2-(Methylthio)benzothiazole	Diphenyl ether
3,3-Dichlorobenzidine	Diphenyl sulfide
3,3-Dimethoxybenzidine	Diphenylamine
3,6-Dimethylphenanthrene	Di-n-butyl phthalate
3-Methylcholanthrene	Di-n-octyl phthalate
3-Nitroaniline	Di-n-propylnitrosamine
4,4-Methylene bis(2-chloroaniline)	Erythritol anhydride
4,5-Methylene phenanthrene	Ethylenethiourea
4-Aminobiphenyl	Ethylmethane sulfonate
4-Bromophenyl phenyl ether	Fluoranthene
4-Chlorophenyl phenyl ether	Fluorene
4-Chloro-2-nitroaniline	Hexachlorobenzene
4-Chloro-3-methylphenol	Hexachlorobutadiene
4-Nitrobiphenyl	Hexachlorocyclopentadiene
4-Nitrophenol	Hexachloroethane
5-Chloro-o-toluidine	Hexachloropropene
5-Nitro-o-toluidine	Hexanoic acid
7,12-Dimehtylbenz(a)anthracene	Indeno(1,2,3-CD)pyrene
Acenaphthene	Isophorone
Acenaphthylene	Isosafrole
Acetophenone	Longifolene
Alpha-terpineol	Malachite green
Aniline	Mestranol
Anthracene	Methapyrilene
Aramite	Methyl methanesulfonate
Benzanthrone	Naphthalene
Benzidine	Nitrobenzene
Benzoic acid	N,n-dimethylformamide
Benzo(a)anthracene	N-decane
Benzo(a)pyrene	N-docosane
Benzo(b)fluoranthene	N-dodecane
Benzo(ghi)perylene	N-eicosane
Benzo(k)fluoranthene	N-hexacosane
Benzyl alcohol	N-hexadecane

Table A-1 (continued)

Biphenyl
bis(2-chloroethoxy)methane
bis(2-chloroethyl)ether
bis(2-chloroisopropyl)ether
bis(2-ethylhexyl)phthalate
bis(chloromethyl)ether
Bromoxynil
Butyl benzyl phthalate
N-nitrosodiethylamine
N-nitrosodimethylamine
N-nitrosodiphenylamine
N-nitrosodi-n-butylamine
N-nitrosomethylethylamine
N-nitrosomethylphenylamine
N-nitrosomorpholine
N-nitrosopiperidine

Semivolatile Organic Compounds

N-octacosane
N-octadecane
N-tetracosane
N-tetradecane
N-triacontane
O-anisidine
O-cresol
O-toluidine
Pentachlorobenzene
Phenacetin
Phenanthrene
Phenol
Phenothiazine
Pronamide
Pyrene
Pyridine
P-chloroaniline
P-cresol
P-cymene
P-dimethylaminoazobenzene
P-nitroaniline
Resorcinol
Safrole
Squalene
Styrene
Thianaphthene
Thioacetamide
Thiophenol
Thioxanthone
Triphenylene
Tripropyleneglycol methyl ether
Pentachloroethane
Pentachlorophenol
Pentamethylbenzene
Perylene

Pesticides and Herbicides

Carbophenothion
Chlordane
Chlorfenvinphos
Chlorobenzilate
Chlorpyrifos
Coumaphos
Crotoxyphos
Cygon
Delta-BHC
Demeton
Diallate
Diazinon
Dichlone
Dichlorvos
Dicrotophos
Dieldrin
Dinoseb
Dioxathion
Disulfoton
Endosulfan I
Endosulfan II
Endosulfan Sulfate
Endrin
Endrin aldehyde
Endrin ketone
EPN
Ethion
Ethylenebisdithiocarbamic acid, salts, and esters
Famphur
Fensulfothion
Fenthion
Gamma-BHC
Heptachlor
Heptachlor epoxide
Hexamethylphosphoramide

TABLE A-1 (continued)

Pesticides and Herbicides

Isodrin
2,4,5-T
2,4,5-TP
2,4-D
4,4'-DDD
4,4'-DDE
4,4'-DDT
Aldrin
Alpha-BHC
Azinphos-ethyl
Azinphos-methyl
Beta-BHC
Captafol
Captan
Kepone
Leptophos
Malathion
Maneb
Methoxychlor
Methyl parathion
Mevinphos
Mirex
Monocrotophos
Nabam
Naled
Nitrofen
Parathion ethyl
PCB-1016

Pesticides and Herbicides

PCB-1221
PCB-1232
PCB-1242
PCB-1248
PCB-1254
PCB-1260
PCNB
Phorate
Phosmet
Phosphamidon
Sulfotepp
Tepp
Terbufos
Tetrachlorvinphos
Thiram
Toxaphene
Trichlorofon
Tricresylphosphate
Trifluralin
Trimethylphosphate
Zineb
Ziram

Dibenzo-p-dioxins
and Dibenzofurans

2,3,7,8-TCDD
Dibenzofuran
Heptachlorodibenzofurans
Heptachlorodibenzo-P-dioxins
Hexachlorodibenzofurans
Hexachlorodibenzo-p-dioxins

Elements

Chromium
Cobalt
Copper
Dysprosium
Erbium
Europium
Gadolinium
Gallium
Germanium
Gold
Hafnium
Holnium
Indium
Iodine
Iridium
Iron
Lanthanum
Lead
Lithium
Lutetium
Magnesium
Manganese
Mercury
Molybdenum
Neodymium
Niobium
Osmium
Palladium
Phosphorus
Platinum
Potassium
Praseodymium

TABLE A-1 (continued)

Octachlorodibenzofurans
Octachlorodibenzo-p-dioxins
Pentachlorodibenzofurans
Pentachlorodibenzo-p-dioxins
Tetrachlorodibenzofurans
Tetrachlorodibenzo-p-dioxins

Elements

Aluminum
Antimony
Arsenic
Barium
Beryllium
Bismuth
Boron
Cadmium
Calcium
Cerium
Rhenium
Rhodium
Ruthenium
Samarium
Scandium
Selenium
Silicon
Silver
Sodium
Strontium
Sulfur
Tantalum
Tellurium
Terbium
Thallium
Thorium
Thulium
Tin
Titanium
Tungsten
Uranium
Vanadium
Ytterbium
Yttrium
Zinc
Zirconium

Conventional Pollutants

BOD5
Oil and Grease, Total Recoverable
pH
TSS

Miscellaneous Pollutants

Ammonia, as N
COD
Conductivity*
Corrosivity
Cyanides
Flash Point
Fluoride
Nitrate/Nitrite
Nitrogen, Kjeldahl, Total
Reactivity*
Residue, Filterable
Salinity (with calcium)*
Salinity (with sodium)*
Sulfide
Total Organic Carbon
Total Phosphorus

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* Analytes not monitored during 1986-87 sampling

APPENDIX B

MAXIMUM PERMISSIBLE CONCENTRATIONS OF POLLUTANTS IN AIR AND WATER

APPENDIX B—CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND

(See notes at end of appendix)

Element (atomic number)	Isotope [1]		Table I		Table II	
			Col. 1—Air (μCi/ml)	Col. 2—Water (μCi/ml)	Col. 1—Air (μCi/ml)	Col. 2—Water (μCi/ml)
Actinium (89)	Ac 227	S	2×10^{-12}	6×10^{-5}	8×10^{-14}	2×10^{-6}
		I	3×10^{-11}	9×10^{-3}	9×10^{-13}	3×10^{-4}
	Ac 228	S	8×10^{-9}	3×10^{-3}	3×10^{-9}	9×10^{-5}
		I	2×10^{-8}	3×10^{-3}	6×10^{-10}	9×10^{-5}
Americium (95)	Am 241	S	6×10^{-13}	1×10^{-3}	2×10^{-14}	4×10^{-6}
		I	1×10^{-10}	8×10^{-4}	4×10^{-13}	3×10^{-5}
	Am 242m	S	6×10^{-12}	1×10^{-3}	2×10^{-13}	4×10^{-5}
		I	3×10^{-10}	3×10^{-3}	9×10^{-12}	9×10^{-5}
	Am 242	S	4×10^{-8}	4×10^{-3}	1×10^{-9}	1×10^{-4}
		I	5×10^{-8}	4×10^{-3}	2×10^{-9}	1×10^{-4}
	Am 243	S	6×10^{-13}	1×10^{-3}	2×10^{-14}	4×10^{-5}
		I	1×10^{-10}	8×10^{-4}	4×10^{-13}	3×10^{-5}
	Am 244	S	4×10^{-8}	1×10^{-3}	1×10^{-9}	5×10^{-5}
		I	2×10^{-8}	1×10^{-3}	8×10^{-10}	5×10^{-5}
Antimony	Sb 122	S	2×10^{-7}	8×10^{-4}	6×10^{-9}	3×10^{-5}
		I	1×10^{-7}	8×10^{-4}	5×10^{-9}	3×10^{-5}
	Sb 124	S	2×10^{-7}	7×10^{-4}	5×10^{-9}	2×10^{-5}
		I	2×10^{-8}	7×10^{-4}	7×10^{-10}	2×10^{-5}
	Sb 125	S	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	3×10^{-8}	3×10^{-3}	9×10^{-10}	1×10^{-4}
Argon (18)	A 37	Sub [2]	8×10^{-5}		1×10^{-6}	
	A 41	Sub	2×10^{-6}		4×10^{-8}	
Arsenic (33)	As 73	S	2×10^{-6}	1×10^{-3}	7×10^{-8}	5×10^{-4}
		I	4×10^{-7}	1×10^{-3}	1×10^{-8}	5×10^{-4}
	As 74	S	3×10^{-7}	2×10^{-3}	1×10^{-8}	8×10^{-5}
		I	1×10^{-7}	2×10^{-3}	4×10^{-9}	5×10^{-5}
	As 76	S	1×10^{-7}	6×10^{-4}	4×10^{-9}	2×10^{-5}
		I	1×10^{-7}	6×10^{-4}	3×10^{-9}	2×10^{-5}
	As 77	S	5×10^{-7}	2×10^{-3}	2×10^{-8}	8×10^{-5}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	8×10^{-5}
Astatine (85)	At 211	S	7×10^{-9}	5×10^{-5}	2×10^{-10}	2×10^{-6}
		I	3×10^{-8}	2×10^{-3}	1×10^{-9}	7×10^{-5}
Barium (56)	Ba 131	S	1×10^{-6}	5×10^{-3}	4×10^{-8}	2×10^{-4}
		I	4×10^{-7}	5×10^{-3}	1×10^{-8}	2×10^{-4}
	Ba 140	S	1×10^{-7}	8×10^{-4}	4×10^{-9}	3×10^{-5}
		I	4×10^{-8}	7×10^{-4}	1×10^{-9}	2×10^{-5}
Berkelium (97)	Bk 249	S	9×10^{-10}	2×10^{-3}	3×10^{-11}	6×10^{-4}
		I	1×10^{-7}	2×10^{-3}	4×10^{-9}	6×10^{-4}
	Bk 250	S	1×10^{-7}	6×10^{-3}	5×10^{-9}	2×10^{-4}
		I	1×10^{-6}	6×10^{-3}	4×10^{-8}	2×10^{-4}
Beryllium (4)	Be 7	S	6×10^{-6}	5×10^{-2}	2×10^{-7}	2×10^{-3}
		I	1×10^{-6}	5×10^{-2}	4×10^{-8}	2×10^{-3}
Bismuth (83)	Bi 206	S	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
		I	1×10^{-7}	1×10^{-3}	5×10^{-9}	4×10^{-5}
	Bi 207	S	2×10^{-7}	2×10^{-3}	6×10^{-9}	6×10^{-5}
		I	1×10^{-8}	2×10^{-3}	5×10^{-10}	6×10^{-5}
	Bi 210	S	6×10^{-9}	1×10^{-3}	2×10^{-10}	4×10^{-5}
		I	6×10^{-8}	1×10^{-3}	2×10^{-10}	4×10^{-5}
	Bi 212	S	1×10^{-7}	1×10^{-3}	3×10^{-9}	4×10^{-5}
		I	2×10^{-7}	1×10^{-3}	7×10^{-9}	4×10^{-5}
Bromine (35)	Br 82	S	1×10^{-6}	8×10^{-3}	4×10^{-8}	3×10^{-4}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
Cadmium (48)	Cd 109	S	5×10^{-8}	5×10^{-3}	2×10^{-9}	2×10^{-4}
		I	7×10^{-8}	5×10^{-3}	3×10^{-9}	2×10^{-4}
	Cd 115m	S	4×10^{-8}	7×10^{-4}	1×10^{-9}	3×10^{-5}
		I	4×10^{-8}	7×10^{-4}	1×10^{-9}	3×10^{-5}
	Cd 115	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	3×10^{-5}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
Calcium (20)	Ca 45	S	3×10^{-8}	3×10^{-4}	1×10^{-9}	9×10^{-6}
		I	1×10^{-7}	5×10^{-3}	4×10^{-9}	2×10^{-4}
	Ca 47	S	2×10^{-7}	1×10^{-3}	6×10^{-9}	5×10^{-5}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	3×10^{-5}
Californium (98)	Cf 249	S	2×10^{-13}	1×10^{-4}	5×10^{-15}	4×10^{-6}
		I	1×10^{-10}	7×10^{-4}	3×10^{-12}	2×10^{-5}
	Cf 250	S	5×10^{-12}	4×10^{-3}	2×10^{-13}	1×10^{-4}
		I	1×10^{-10}	7×10^{-4}	3×10^{-12}	3×10^{-5}
	Cf 251	S	2×10^{-13}	1×10^{-4}	6×10^{-15}	4×10^{-6}
		I	1×10^{-10}	8×10^{-4}	3×10^{-12}	3×10^{-5}
	Cf 252	S	6×10^{-13}	2×10^{-4}	2×10^{-14}	7×10^{-6}
		I	3×10^{-11}	2×10^{-4}	1×10^{-12}	7×10^{-6}
	Cf 253	S	8×10^{-10}	4×10^{-3}	3×10^{-11}	1×10^{-4}
		I	8×10^{-10}	4×10^{-3}	3×10^{-11}	1×10^{-4}
	Cf 254	S	5×10^{-13}	4×10^{-3}	2×10^{-14}	1×10^{-4}
		I	5×10^{-12}	4×10^{-3}	2×10^{-13}	1×10^{-4}

Table B-1 Source: 10 CFR 20, Nuclear Regulatory Commission Standards for Protection Against Radiation, pp. 151: 4112.3–4117.

[Appendix B]

APPENDIX B—Continued

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND—continued

[See notes at end of appendix]

Element (atomic number)	Isotope [1]		Table I		Table II	
			Column 1 Air (μc/ml)	Column 2 Water (μc/ml)	Column 1 Air (μc/ml)	Column 2 Water (μc/ml)
Carbon (6)	C 14	B	4×10⁻⁶	2×10⁻³	1×10⁻⁷	8×10⁻⁶
	(CO_2)	Sub	5×10⁻⁶		1×10⁻⁶	
Cerium (58)	Ce 141	S	4×10⁻⁵	3×10⁻³	2×10⁻⁶	9×10⁻⁶
		I	2×10⁻⁵	3×10⁻³	3×10⁻⁶	9×10⁻⁶
	Ce 143	S	3×10⁻⁵	1×10⁻³	9×10⁻⁷	4×10⁻⁶
		I	2×10⁻⁵	1×10⁻³	7×10⁻⁶	4×10⁻⁶
	Ce 144	S	1×10⁻⁶	5×10⁻⁴	3×10⁻¹⁰	1×10⁻⁶
		I	6×10⁻⁶	5×10⁻⁴	2×10⁻⁹	1×10⁻⁶
Cesium (55)	Cs 131	S	1×10⁻⁵	7×10⁻³	4×10⁻⁷	2×10⁻⁵
		I	3×10⁻⁶	3×10⁻³	1×10⁻⁷	9×10⁻⁶
	Cs 134m	S	4×10⁻⁵	2×10⁻³	1×10⁻⁶	6×10⁻⁶
		I	6×10⁻⁶	3×10⁻³	2×10⁻⁷	1×10⁻⁵
	Cs 134	S	4×10⁻⁶	3×10⁻⁴	1×10⁻⁸	9×10⁻⁷
		I	1×10⁻⁶	1×10⁻³	4×10⁻¹⁰	4×10⁻⁶
	Cs 135	S	5×10⁻⁷	3×10⁻³	2×10⁻⁸	1×10⁻⁵
		I	9×10⁻⁶	7×10⁻³	3×10⁻⁸	2×10⁻⁵
	Cs 136	S	4×10⁻⁷	2×10⁻³	1×10⁻⁸	9×10⁻⁶
		I	2×10⁻⁷	2×10⁻³	6×10⁻⁹	6×10⁻⁶
	Cs 137	S	6×10⁻⁶	4×10⁻⁴	2×10⁻⁸	2×10⁻⁶
		I	1×10⁻⁶	1×10⁻³	5×10⁻¹⁰	4×10⁻⁶
Chlorine (17)	Cl 36	S	4×10⁻⁷	2×10⁻³	1×10⁻⁸	8×10⁻⁶
		I	2×10⁻⁶	2×10⁻³	8×10⁻¹⁰	6×10⁻⁶
	Cl 38	S	3×10⁻⁶	1×10⁻³	9×10⁻⁸	4×10⁻⁶
		I	2×10⁻⁶	1×10⁻³	7×10⁻⁸	4×10⁻⁶
Chromium (24)	Cr 51	S	1×10⁻⁵	5×10⁻³	4×10⁻⁷	2×10⁻⁵
		I	2×10⁻⁶	7×10⁻³	8×10⁻⁸	2×10⁻⁵
Cobalt (27)	Co 57	S	3×10⁻⁶	2×10⁻⁴	1×10⁻⁷	8×10⁻⁶
		I	2×10⁻⁷	1×10⁻³	6×10⁻⁹	4×10⁻⁶
	Co 58m	S	2×10⁻⁵	8×10⁻³	6×10⁻⁷	3×10⁻⁵
		I	9×10⁻⁶	6×10⁻³	3×10⁻⁷	2×10⁻⁵
	Co 58	S	8×10⁻⁷	4×10⁻³	3×10⁻⁸	1×10⁻⁵
		I	6×10⁻⁶	3×10⁻³	2×10⁻⁸	9×10⁻⁶
	Co 60	S	3×10⁻⁷	1×10⁻³	1×10⁻⁸	5×10⁻⁶
		I	9×10⁻⁷	1×10⁻³	3×10⁻¹⁰	3×10⁻⁶
Copper (29)	Cu 64	S	2×10⁻⁶	1×10⁻³	7×10⁻⁸	3×10⁻⁶
		I	1×10⁻⁶	6×10⁻³	4×10⁻⁸	2×10⁻⁵
Curium (96)	Cm 242	S	1×10⁻¹⁰	7×10⁻⁴	4×10⁻¹³	2×10⁻⁶
		I	2×10⁻¹⁰	7×10⁻⁴	6×10⁻¹³	2×10⁻⁶
	Cm 243	S	6×10⁻¹³	1×10⁻⁴	2×10⁻¹⁵	5×10⁻⁷
		I	1×10⁻¹⁰	7×10⁻⁴	3×10⁻¹³	2×10⁻⁶
	Cm 244	S	2×10⁻¹³	1×10⁻⁴	5×10⁻¹⁵	7×10⁻⁷
		I	1×10⁻¹⁰	8×10⁻⁴	3×10⁻¹³	3×10⁻⁶
	Cm 245	S	8×10⁻¹⁵	1×10⁻⁴	2×10⁻¹⁵	4×10⁻⁷
		I	1×10⁻¹⁰	9×10⁻⁴	4×10⁻¹³	3×10⁻⁶
	Cm 246	S	8×10⁻¹³	1×10⁻⁴	2×10⁻¹⁵	4×10⁻⁷
		I	1×10⁻¹⁰	9×10⁻⁴	4×10⁻¹³	3×10⁻⁶
	Cm 247	S	8×10⁻¹³	1×10⁻⁴	2×10⁻¹⁵	4×10⁻⁷
		I	1×10⁻¹⁰	6×10⁻⁴	4×10⁻¹³	2×10⁻⁶
	Cm 248	S	6×10⁻¹³	1×10⁻⁴	2×10⁻¹⁵	4×10⁻⁷
		I	1×10⁻¹¹	4×10⁻⁵	4×10⁻¹⁵	1×10⁻⁶
	Cm 249	S	1×10⁻⁴	6×10⁻²	4×10⁻⁷	2×10⁻³
		I	1×10⁻⁴	6×10⁻²	4×10⁻⁷	2×10⁻³
Dysprosium (66)	Dy 165	S	3×10⁻⁶	1×10⁻³	9×10⁻⁸	4×10⁻⁶
		I	2×10⁻⁶	1×10⁻³	7×10⁻⁸	4×10⁻⁶
	Dy 166	S	2×10⁻⁷	1×10⁻³	8×10⁻⁹	4×10⁻⁶
		I	2×10⁻⁷	1×10⁻³	7×10⁻⁹	4×10⁻⁶
Einsteinium (99)	Es 253	S	8×10⁻¹⁰	7×10⁻⁴	3×10⁻¹¹	2×10⁻⁶
		I	6×10⁻¹⁰	7×10⁻⁴	2×10⁻¹¹	2×10⁻⁶
	Es 254m	S	5×10⁻⁸	5×10⁻⁴	2×10⁻¹⁰	2×10⁻⁶
		I	6×10⁻⁸	5×10⁻⁴	2×10⁻¹⁰	2×10⁻⁶
	Es 254	S	2×10⁻¹¹	4×10⁻⁴	6×10⁻¹³	1×10⁻⁶
		I	1×10⁻¹⁰	4×10⁻⁴	4×10⁻¹³	1×10⁻⁶
	Es 255	S	6×10⁻¹⁰	8×10⁻⁴	2×10⁻¹¹	3×10⁻⁶
		I	4×10⁻¹⁰	8×10⁻⁴	1×10⁻¹¹	3×10⁻⁶
Erbium (68)	Er 169	S	6×10⁻⁷	3×10⁻³	2×10⁻⁸	9×10⁻⁶
		I	4×10⁻⁷	3×10⁻³	1×10⁻⁸	9×10⁻⁶
	Er 171	S	7×10⁻⁷	3×10⁻³	2×10⁻⁸	1×10⁻⁵
		I	6×10⁻⁷	3×10⁻³	2×10⁻⁸	1×10⁻⁵
Europium (63)	Eu 152 ($T_{1/2}$ = 9.2 hrs)	S	4×10⁻⁷	2×10⁻³	1×10⁻⁸	6×10⁻⁶
		I	3×10⁻⁷	2×10⁻³	1×10⁻⁸	6×10⁻⁶
	Eu 152 ($T_{1/2}$ = 13 yrs)	S	1×10⁻⁶	2×10⁻⁴	4×10⁻¹⁰	8×10⁻⁷
		I	2×10⁻⁶	7×10⁻⁴	6×10⁻¹⁰	8×10⁻⁷
	Eu 154	S	6×10⁻⁷	6×10⁻⁴	1×10⁻¹⁰	2×10⁻⁶
		I	5×10⁻⁷	6×10⁻⁴	2×10⁻¹⁰	2×10⁻⁶
	Eu 155	S	9×10⁻⁷	6×10⁻³	3×10⁻⁹	2×10⁻⁵
		I	7×10⁻⁷	6×10⁻³	3×10⁻⁹	2×10⁻⁵
Fermium (100)	Fm 254	S	6×10⁻⁶	4×10⁻³	2×10⁻⁹	1×10⁻⁵
		I	7×10⁻⁶	4×10⁻³	2×10⁻⁹	1×10⁻⁵
	Fm 255	S	2×10⁻⁶	1×10⁻³	6×10⁻¹⁰	3×10⁻⁶
		I	1×10⁻⁶	1×10⁻³	4×10⁻¹⁰	3×10⁻⁶
	Fm 256	S	5×10⁻⁶	3×10⁻³	1×10⁻⁹	9×10⁻⁶
		I	2×10⁻⁶	3×10⁻³	6×10⁻¹¹	9×10⁻⁶
Fluorine (9)	F 18	S	5×10⁻⁶	2×10⁻³	2×10⁻⁷	8×10⁻⁶
		I	3×10⁻⁶	1×10⁻³	9×10⁻⁸	5×10⁻⁶
Gadolinium (64)	Gd 153	S	2×10⁻⁷	6×10⁻³	5×10⁻⁹	2×10⁻⁵
		I	9×10⁻⁷	6×10⁻³	3×10⁻⁹	2×10⁻⁵
	Gd 159	S	5×10⁻⁷	2×10⁻³	2×10⁻⁸	6×10⁻⁶
		I	4×10⁻⁷	2×10⁻³	1×10⁻⁸	9×10⁻⁶
Gallium (31)	Ga 72	S	2×10⁻⁷	1×10⁻³	5×10⁻⁹	4×10⁻⁶
		I	2×10⁻⁷	1×10⁻³	6×10⁻⁹	4×10⁻⁶
Germanium (32)	Ge 71	S	1×10⁻⁶	8×10⁻³	4×10⁻⁸	3×10⁻⁵
		I	6×10⁻⁶	5×10⁻³	2×10⁻⁷	2×10⁻⁵
Gold (79)	Au 196	S	1×10⁻⁶	5×10⁻⁴	4×10⁻⁹	2×10⁻⁶
		I	6×10⁻⁷	4×10⁻⁴	2×10⁻⁹	1×10⁻⁶
	Au 198	S	3×10⁻⁷	2×10⁻³	1×10⁻⁸	8×10⁻⁶
		I	2×10⁻⁷	1×10⁻³	8×10⁻⁹	6×10⁻⁶
	Au 199	S	1×10⁻⁶	8×10⁻⁴	4×10⁻⁹	3×10⁻⁶

APPENDIX B—Continued

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND—continued

[See notes at end of appendix]

Element (atomic number)	Isotope [1]		Table I		Table II	
			Column 1 Air (μc/ml)	Column 2 Water (μc/ml)	Column 1 Air (μc/ml)	Column 2 Water (μc/ml)
Hafnium (72)	Hf 181	I	8X10⁻⁷	4X10⁻⁴	3X10⁻⁸	2X10⁻⁵
		S	4X10⁻⁶	2X10⁻³	1X10⁻⁷	7X10⁻⁵
Holmium (67)	Ho 166	I	7X10⁻⁷	3X10⁻⁴	3X10⁻⁸	1X10⁻⁵
		S	2X10⁻⁷	9X10⁻⁴	7X10⁻⁹	3X10⁻⁵
Hydrogen (1)	H3	I	2X10⁻⁶	9X10⁻³	6X10⁻⁸	3X10⁻⁴
		S	8X10⁻⁶	3X10⁻²	2X10⁻⁷	2X10⁻³
		I	3X10⁻⁶	1X10⁻²	2X10⁻⁷	3X10⁻³
		Sub	2X10⁻⁶	----------	4X10⁻⁸	----------
Iridium (49)	In 113m	S	8X10⁻⁷	4X10⁻³	3X10⁻⁸	1X10⁻⁴
		I	7X10⁻⁷	4X10⁻³	2X10⁻⁷	1X10⁻⁴
	In 114m	S	1X10⁻⁷	8X10⁻⁴	4X10⁻⁹	2X10⁻⁵
		I	2X10⁻⁷	8X10⁻⁴	7X10⁻⁹	2X10⁻⁵
	In 115m	S	7X10⁻⁷	3X10⁻³	8X10⁻⁸	4X10⁻⁴
		I	2X10⁻⁶	1X10⁻²	[illegible]	[illegible]
	In 115	S	2X10⁻⁷	3X10⁻⁹	9X10⁻⁹	9X10⁻⁸
		I	3X10⁻⁶	3X10⁻⁸	1X10⁻⁸	6X10⁻⁷
Iodine (53)	I 125	S	8X10⁻⁹	4X10⁻⁶	9X10⁻¹¹	2X10⁻⁷
		I	2X10⁻⁷	8X10⁻⁶	6X10⁻⁹	2X10⁻⁷
	I 126	S	8X10⁻⁹	4X10⁻⁶	9X10⁻¹¹	3X10⁻⁷
		I	3X10⁻⁷	3X10⁻⁶	1X10⁻⁸	1X10⁻⁷
	I 129	S	2X10⁻⁹	1X10⁻⁶	2X10⁻¹¹	6X10⁻⁸
		I	7X10⁻⁷	6X10⁻⁶	2X10⁻⁸	2X10⁻⁷
	I 131	S	9X10⁻⁹	6X10⁻⁶	1X10⁻¹⁰	3X10⁻⁷
		I	3X10⁻⁷	2X10⁻⁶	1X10⁻⁸	6X10⁻⁸
	I 132	S	2X10⁻⁷	2X10⁻⁵	3X10⁻⁹	8X10⁻⁷
		I	9X10⁻⁷	6X10⁻⁵	2X10⁻⁸	2X10⁻⁶
	I 133	S	3X10⁻⁸	2X10⁻⁶	4X10⁻¹⁰	1X10⁻⁷
		I	2X10⁻⁷	1X10⁻⁵	7X10⁻⁹	4X10⁻⁶
	I 134	S	5X10⁻⁷	4X10⁻⁵	6X10⁻⁸	2X10⁻⁶
		I	3X10⁻⁶	2X10⁻⁴	2X10⁻⁷	6X10⁻⁶
	I 135	S	1X10⁻⁷	7X10⁻⁵	1X10⁻⁹	4X10⁻⁶
		I	4X10⁻⁷	2X10⁻⁴	1X10⁻⁸	7X10⁻⁶
Iridium (77)	Ir 190	S	1X10⁻⁶	6X10⁻⁴	4X10⁻⁸	2X10⁻⁵
		I	4X10⁻⁷	8X10⁻⁴	1X10⁻⁸	2X10⁻⁵
	Ir 192	S	1X10⁻⁷	1X10⁻⁴	4X10⁻⁹	4X10⁻⁶
		I	3X10⁻⁷	1X10⁻⁴	9X10⁻¹⁰	4X10⁻⁶
	Ir 194	S	2X10⁻⁷	1X10⁻⁴	8X10⁻⁹	3X10⁻⁶
		I	2X10⁻⁷	9X10⁻⁴	5X10⁻⁹	3X10⁻⁶
Iron (26)	Fe 55	S	9X10⁻⁷	2X10⁻³	3X10⁻⁸	8X10⁻⁵
		I	1X10⁻⁶	7X10⁻³	3X10⁻⁸	2X10⁻⁴
	Fe 59	S	1X10⁻⁷	2X10⁻⁴	8X10⁻⁹	6X10⁻⁶
		I	5X10⁻⁷	2X10⁻⁴	[illegible]	5X10⁻⁶
Krypton [4] (36)	Kr 85m	Sub	6X10⁻⁶	----------	1X10⁻⁷	----------
	Kr 85	Sub	1X10⁻⁵	----------	3X10⁻⁷	----------
	Kr 87	Sub	1X10⁻⁶	----------	2X10⁻⁸	----------
	Kr 88	Sub	1X10⁻⁶	----------	2X10⁻⁸	----------
Lanthanum (57)	La 140	S	2X10⁻⁷	7X10⁻⁴	8X10⁻⁹	2X10⁻⁵
		I	1X10⁻⁷	7X10⁻⁴	4X10⁻⁹	2X10⁻⁴
Lead (82)	Pb 203	S	3X10⁻⁶	1X10⁻³	9X10⁻⁸	4X10⁻⁴
		I	2X10⁻⁶	1X10⁻³	6X10⁻⁸	4X10⁻⁴
	Pb 210	S	1X10⁻¹⁰	4X10⁻⁶	4X10⁻¹⁰	1X10⁻⁷
		I	2X10⁻¹⁰	3X10⁻⁶	8X10⁻¹⁰	2X10⁻⁷
	Pb 212	S	2X10⁻⁸	6X10⁻⁵	6X10⁻¹⁰	2X10⁻⁶
		I	2X10⁻⁸	5X10⁻⁵	7X10⁻¹⁰	2X10⁻⁶
Lutetium (71)	Lu 177	S	6X10⁻⁷	3X10⁻³	2X10⁻⁸	1X10⁻⁴
		I	5X10⁻⁷	3X10⁻³	2X10⁻⁸	1X10⁻⁴
Manganese (25)	Mn 52	S	2X10⁻⁷	1X10⁻³	7X10⁻⁹	3X10⁻⁵
		I	1X10⁻⁷	8X10⁻⁴	5X10⁻⁹	3X10⁻⁵
	Mn 54	S	4X10⁻⁷	4X10⁻³	1X10⁻⁸	1X10⁻⁴
		I	4X10⁻⁷	3X10⁻³	1X10⁻⁸	1X10⁻⁴
	Mn 56	S	8X10⁻⁷	4X10⁻³	3X10⁻⁸	1X10⁻⁴
		I	5X10⁻⁷	3X10⁻³	2X10⁻⁸	1X10⁻⁴
Mercury (80)	Hg 197m	S	7X10⁻⁷	6X10⁻³	3X10⁻⁸	2X10⁻⁴
		I	6X10⁻⁷	5X10⁻³	3X10⁻⁸	2X10⁻⁴
	Hg 197	S	1X10⁻⁶	9X10⁻³	4X10⁻⁸	3X10⁻⁴
		I	3X10⁻⁶	1X10⁻²	9X10⁻⁸	6X10⁻⁴
	Hg 203	S	7X10⁻⁷	5X10⁻⁴	2X10⁻⁸	2X10⁻⁵
		I	1X10⁻⁷	3X10⁻⁴	4X10⁻⁹	1X10⁻⁵
Molybdenum (42)	Mo 99	S	7X10⁻⁷	5X10⁻³	3X10⁻⁸	2X10⁻⁴
		I	2X10⁻⁷	1X10⁻³	7X10⁻⁹	4X10⁻⁵
Neodymium (60)	Nd 144	S	6X10⁻¹¹	2X10⁻⁶	3X10⁻¹⁰	7X10⁻⁸
		I	3X10⁻¹⁰	2X10⁻⁶	1X10⁻¹⁰	8X10⁻⁸
	Nd 147	S	4X10⁻⁷	2X10⁻³	1X10⁻⁸	6X10⁻⁵
		I	2X10⁻⁷	2X10⁻³	8X10⁻⁹	6X10⁻⁵
	Nd 149	S	2X10⁻⁶	9X10⁻³	6X10⁻⁸	3X10⁻⁴
		I	1X10⁻⁶	8X10⁻³	6X10⁻⁸	3X10⁻⁴
Neptunium (93)	Np 237	S	4X10⁻¹²	9X10⁻⁶	1X10⁻¹⁰	3X10⁻⁷
		I	1X10⁻¹⁰	9X10⁻⁶	6X10⁻¹⁰	3X10⁻⁷
	Np 239	S	8X10⁻⁷	4X10⁻³	3X10⁻⁸	1X10⁻⁴
		I	7X10⁻⁷	4X10⁻³	2X10⁻⁸	1X10⁻⁴
Nickel (28)	Ni 59	S	8X10⁻⁷	6X10⁻³	2X10⁻⁸	2X10⁻⁴
		I	6X10⁻⁷	6X10⁻³	3X10⁻¹⁰	2X10⁻⁴
	Ni 63	S	6X10⁻⁶	8X10⁻³	2X10⁻⁸	3X10⁻⁴
		I	3X10⁻⁷	2X10⁻³	1X10⁻⁸	7X10⁻⁵
	Ni 65	S	9X10⁻⁷	4X10⁻³	3X10⁻⁸	1X10⁻⁴
		I	8X10⁻⁷	3X10⁻³	2X10⁻⁸	1X10⁻⁴
Niobium (Columbium) (41)	Nb 93m	S	1X10⁻⁷	1X10⁻³	4X10⁻⁹	4X10⁻⁵
		I	2X10⁻⁷	1X10⁻³	6X10⁻⁹	4X10⁻⁵
	Nb 95	S	8X10⁻⁷	3X10⁻³	2X10⁻⁸	1X10⁻⁴
		I	1X10⁻⁷	3X10⁻³	3X10⁻⁹	1X10⁻⁴
	Nb 97	S	6X10⁻⁶	3X10⁻³	2X10⁻⁸	9X10⁻⁵
		I	4X10⁻⁶	4X10⁻³	2X10⁻⁸	9X10⁻⁵
Osmium (76)	Os 185	S	8X10⁻⁷	3X10⁻³	3X10⁻⁸	7X10⁻⁵
		I	8X10⁻⁷	9X10⁻³	3X10⁻⁸	7X10⁻⁵
	Os 191m	S	2X10⁻⁶	2X10⁻²	6X10⁻⁸	3X10⁻⁴
		I	9X10⁻⁶	7X10⁻³	3X10⁻⁷	2X10⁻⁴

TABLE B-1

APPENDIX B—Continued

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND—continued

[See notes at end of appendix]

Element (atomic number)	Isotope [1]		Table I		Table II	
			Column 1 Air (μc/ml)	Column 2 Water (μc/ml)	Column 1 Air (μc/ml)	Column 2 Water (μc/ml)
	Os 191	S	1X10⁻⁶	3X10⁻⁵	4X10⁻⁶	2X10⁻⁴
		I	4X10⁻⁷	8X10⁻⁶	1X10⁻⁶	2X10⁻⁴
	Os 193	S	4X10⁻⁷	2X10⁻⁵	1X10⁻⁶	6X10⁻⁵
		I	3X10⁻⁷	2X10⁻⁵	9X10⁻⁷	6X10⁻⁵
Palladium (46)	Pd 103	S	1X10⁻⁶	1X10⁻⁴	3X10⁻⁶	3X10⁻³
		I	7X10⁻⁷	6X10⁻⁵	3X10⁻⁶	2X10⁻³
	Pd 109	S	6X10⁻⁷	3X10⁻⁵	2X10⁻⁶	9X10⁻⁴
		I	4X10⁻⁷	2X10⁻⁵	1X10⁻⁶	7X10⁻⁴
Phosphorus (15)	P 32	S	7X10⁻⁸	8X10⁻⁶	2X10⁻⁷	2X10⁻⁴
		I	8X10⁻⁸	7X10⁻⁶	3X10⁻⁷	2X10⁻⁴
Platinum (78)	Pt 191	S	8X10⁻⁷	4X10⁻⁵	3X10⁻⁶	1X10⁻³
		I	6X10⁻⁷	3X10⁻⁵	2X10⁻⁶	1X10⁻³
	Pt 193m	S	7X10⁻⁶	3X10⁻⁴	2X10⁻⁵	1X10⁻²
		I	8X10⁻⁶	3X10⁻⁴	2X10⁻⁵	1X10⁻²
	Pt 197m	S	6X10⁻⁶	3X10⁻⁴	2X10⁻⁵	1X10⁻²
		I	8X10⁻⁶	3X10⁻⁴	2X10⁻⁵	1X10⁻²
	Pt 197	S	8X10⁻⁷	4X10⁻⁵	3X10⁻⁶	1X10⁻³
		I	6X10⁻⁷	3X10⁻⁵	2X10⁻⁶	1X10⁻³
Plutonium (94)	Pu 238	S	2X10⁻¹²	1X10⁻⁸	7X10⁻¹⁴	4X10⁻⁷
		I	3X10⁻¹²	8X10⁻⁸	1X10⁻¹³	3X10⁻⁶
	Pu 239	S	2X10⁻¹²	1X10⁻⁸	6X10⁻¹⁴	4X10⁻⁷
		I	4X10⁻¹²	8X10⁻⁸	1X10⁻¹³	3X10⁻⁶
	Pu 240	S	2X10⁻¹²	1X10⁻⁸	6X10⁻¹⁴	4X10⁻⁷
		I	4X10⁻¹²	8X10⁻⁸	1X10⁻¹³	3X10⁻⁶
	Pu 241	S	9X10⁻¹¹	7X10⁻⁷	3X10⁻¹²	2X10⁻⁵
		I	4X10⁻¹⁰	4X10⁻⁷	1X10⁻¹²	1X10⁻⁵
	Pu 242	S	2X10⁻¹²	1X10⁻⁸	6X10⁻¹⁴	4X10⁻⁷
		I	4X10⁻¹²	9X10⁻⁸	1X10⁻¹³	3X10⁻⁶
	Pu 243	S	2X10⁻⁸	1X10⁻⁴	6X10⁻¹⁰	3X10⁻³
		I	2X10⁻⁸	1X10⁻⁴	6X10⁻¹⁰	3X10⁻³
	Pu 244	S	2X10⁻¹²	1X10⁻⁸	6X10⁻¹⁴	4X10⁻⁷
		I	3X10⁻¹²	3X10⁻⁸	1X10⁻¹³	1X10⁻⁶
Polonium (84)	Po 210	S	8X10⁻¹⁰	2X10⁻⁵	2X10⁻¹¹	7X10⁻⁴
		I	2X10⁻⁹	8X10⁻⁵	7X10⁻¹¹	3X10⁻³
Potassium (19)	K 42	S	2X10⁻⁸	9X10⁻⁴	7X10⁻⁹	3X10⁻²
Praseodymium (59)	Pr 142	S	1X10⁻⁷	6X10⁻⁴	4X10⁻⁸	2X10⁻²
		I	2X10⁻⁷	9X10⁻⁴	7X10⁻⁹	3X10⁻²
	Pr 143	S	2X10⁻⁷	9X10⁻⁴	6X10⁻⁸	3X10⁻²
		I	3X10⁻⁷	1X10⁻³	1X10⁻⁸	5X10⁻²
Promethium (61)	Pm 147	S	2X10⁻⁷	1X10⁻³	6X10⁻⁹	5X10⁻²
		I	6X10⁻⁸	2X10⁻⁴	2X10⁻⁹	7X10⁻³
	Pm 149	S	1X10⁻⁷	6X10⁻⁴	3X10⁻⁸	2X10⁻²
		I	3X10⁻⁷	1X10⁻³	1X10⁻⁸	4X10⁻²
Protoactinium (91)	Pa 230	S	2X10⁻⁷	1X10⁻³	8X10⁻⁹	4X10⁻²
		I	2X10⁻⁶	7X10⁻³	6X10⁻¹¹	2X10⁻⁴
	Pa 231	S	8X10⁻¹⁰	7X10⁻⁶	3X10⁻¹¹	2X10⁻⁴
		I	1X10⁻¹²	3X10⁻⁸	4X10⁻¹⁴	9X10⁻⁷
	Pa 233	S	1X10⁻⁸	8X10⁻⁵	4X10⁻¹³	2X10⁻³
		I	6X10⁻⁸	4X10⁻⁴	2X10⁻⁹	1X10⁻²
Radium (88)	Ra 223	S	2X10⁻⁸	3X10⁻⁵	6X10⁻¹⁰	1X10⁻³
		I	4X10⁻⁸	2X10⁻⁴	1X10⁻⁹	6X10⁻³
	Ra 224	S	2X10⁻¹⁰	1X10⁻⁶	8X10⁻¹²	4X10⁻⁵
		I	8X10⁻⁹	2X10⁻⁴	2X10⁻¹⁰	2X10⁻³
	Ra 226	S	7X10⁻¹³	2X10⁻⁶	2X10⁻¹⁴	6X10⁻⁵
		I	3X10⁻¹¹	4X10⁻⁷	2X10⁻¹²	2X10⁻⁵
	Ra 228	S	8X10⁻¹³	9X10⁻⁶	2X10⁻¹⁴	3X10⁻⁷
		I	7X10⁻¹¹	6X10⁻⁷	2X10⁻¹²	3X10⁻⁵
Radon (86)	Rn 220	S	4X10⁻⁷	7X10⁻⁴	1X10⁻⁸	3X10⁻²
		I	3X10⁻⁷	----------	1X10⁻⁸	----------
	Rn 222 [3]	S	3X10⁻⁶	----------	3X10⁻⁸	----------
Rhenium (75)	Re 183	S	3X10⁻⁶	2X10⁻³	9X10⁻⁸	6X10⁻²
	Re 186	I	2X10⁻⁶	8X10⁻⁴	8X10⁻⁸	3X10⁻²
		S	6X10⁻⁷	3X10⁻³	2X10⁻⁸	9X10⁻²
	Re 187	I	2X10⁻⁶	1X10⁻³	8X10⁻⁸	5X10⁻²
		S	9X10⁻⁶	7X10⁻³	3X10⁻⁷	2X10⁻¹
	Re 188	I	5X10⁻⁷	4X10⁻³	2X10⁻⁸	2X10⁻¹
		S	4X10⁻⁷	2X10⁻³	1X10⁻⁸	6X10⁻²
Rhodium (45)	Rh 103m	I	2X10⁻⁶	9X10⁻⁴	6X10⁻⁸	3X10⁻²
		S	8X10⁻⁶	4X10⁻²	3X10⁻⁷	1X10⁻¹
	Rh 105	I	6X10⁻⁶	3X10⁻²	2X10⁻⁷	1X10⁻¹
		S	8X10⁻⁷	4X10⁻³	3X10⁻⁸	1X10⁻²
Rubidium (37)	Rb 86	I	8X10⁻⁷	3X10⁻³	2X10⁻⁸	1X10⁻²
		S	3X10⁻⁷	2X10⁻³	1X10⁻⁸	7X10⁻²
	Rb 87	I	7X10⁻⁷	7X10⁻³	2X10⁻⁸	2X10⁻¹
		S	8X10⁻⁷	3X10⁻³	2X10⁻⁸	1X10⁻²
		I	7X10⁻⁶	8X10⁻³	2X10⁻⁸	2X10⁻²
Ruthenium (44)	Ru 97	S	2X10⁻⁶	1X10⁻²	8X10⁻⁸	4X10⁻²
		I	2X10⁻⁶	1X10⁻²	6X10⁻⁸	3X10⁻²
	Ru 103	S	5X10⁻⁷	2X10⁻³	2X10⁻⁸	8X10⁻²
		I	6X10⁻⁷	2X10⁻³	3X10⁻⁸	6X10⁻²
	Ru 105	S	7X10⁻⁷	2X10⁻³	2X10⁻⁸	1X10⁻²
		I	8X10⁻⁷	3X10⁻³	2X10⁻⁸	1X10⁻²
	Ru 106	S	8X10⁻⁹	4X10⁻⁵	3X10⁻¹⁰	1X10⁻³
		I	6X10⁻⁹	3X10⁻⁵	2X10⁻¹⁰	1X10⁻³
Samarium (62)	Sm 147	S	7X10⁻¹³	2X10⁻⁶	2X10⁻¹⁴	8X10⁻⁵
		I	3X10⁻¹²	2X10⁻⁶	9X10⁻¹⁴	7X10⁻⁵
	Sm 151	S	6X10⁻⁹	1X10⁻³	2X10⁻¹⁰	4X10⁻²
		I	1X10⁻⁸	1X10⁻³	8X10⁻¹⁰	4X10⁻²
	Sm 153	S	2X10⁻⁷	2X10⁻³	2X10⁻⁹	6X10⁻²
		I	4X10⁻⁷	2X10⁻³	1X10⁻⁸	5X10⁻²
Scandium (21)	Sc 46	S	2X10⁻⁸	1X10⁻⁴	8X10⁻¹⁰	4X10⁻³
		I	2X10⁻⁸	1X10⁻⁴	6X10⁻¹⁰	4X10⁻³
	Sc 47	S	6X10⁻⁷	3X10⁻³	2X10⁻⁸	9X10⁻²
		I	9X10⁻⁷	3X10⁻³	2X10⁻⁸	9X10⁻²
	Sc 48	S	2X10⁻⁷	8X10⁻⁴	6X10⁻⁹	3X10⁻²
		I	3X10⁻⁷	8X10⁻⁴	8X10⁻⁹	3X10⁻²

APPENDIX B—Continued

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND—continued

[See notes at end of appendix]

Element (atomic number)	Isotope [1]		Table I		Table II	
			Column 1 Air (μc/ml)	Column 2 Water (μc/ml)	Column 1 Air (μc/ml)	Column 2 Water (μc/ml)
Selenium (34)	Se 75	S	1X10⁻⁶	9X10⁻³	4X10⁻⁹	3X10⁻⁶
		I	1X10⁻⁷	8X10⁻³	4X10⁻⁹	3X10⁻⁶
Silicon (14)	Si 31	S	6X10⁻⁶	3X10⁻²	2X10⁻⁷	9X10⁻⁶
		I	1X10⁻⁶	6X10⁻³	3X10⁻⁸	2X10⁻⁶
Silver (47)	Ag 105	S	6X10⁻⁷	3X10⁻³	2X10⁻⁷	1X10⁻⁶
		I	8X10⁻⁷	3X10⁻³	3X10⁻⁸	1X10⁻⁶
	Ag 110m	S	2X10⁻⁷	9X10⁻⁴	7X10⁻⁹	3X10⁻⁶
		I	1X10⁻⁷	9X10⁻⁴	3X10⁻⁹	3X10⁻⁶
	Ag 111	S	3X10⁻⁷	1X10⁻³	1X10⁻⁸	4X10⁻⁶
		I	2X10⁻⁷	1X10⁻³	6X10⁻⁹	4X10⁻⁶
Sodium (11)	Na 22	S	2X10⁻⁷	1X10⁻³	6X10⁻⁹	4X10⁻⁶
		I	9X10⁻⁷	9X10⁻⁴	3X10⁻⁸	3X10⁻⁶
	Na 24	S	1X10⁻⁶	6X10⁻³	4X10⁻⁸	2X10⁻⁵
		I	1X10⁻⁷	8X10⁻⁴	5X10⁻⁹	3X10⁻⁶
Strontium (38)	Sr 85m	S	4X10⁻⁶	2X10⁻²	1X10⁻⁷	7X10⁻⁵
		I	3X10⁻⁶	2X10⁻²	1X10⁻⁸	7X10⁻⁵
	Sr 85	S	2X10⁻⁷	3X10⁻³	8X10⁻⁹	1X10⁻⁶
		I	1X10⁻⁷	8X10⁻³	4X10⁻⁹	2X10⁻⁶
	Sr 89	S	3X10⁻⁸	3X10⁻⁴	3X10⁻¹⁰	3X10⁻⁶
		I	4X10⁻⁸	6X10⁻⁴	1X10⁻⁹	3X10⁻⁶
	Sr 90	S	1X10⁻⁹	1X10⁻⁴	3X10⁻¹¹	3X10⁻⁷
		I	5X10⁻⁹	1X10⁻³	2X10⁻¹⁰	4X10⁻⁶
	Sr 91	S	4X10⁻⁷	2X10⁻³	2X10⁻⁸	7X10⁻⁶
		I	3X10⁻⁷	1X10⁻³	9X10⁻⁹	5X10⁻⁶
	Sr 92	S	4X10⁻⁷	2X10⁻³	2X10⁻⁸	7X10⁻⁶
		I	3X10⁻⁷	2X10⁻³	1X10⁻⁸	6X10⁻⁶
Sulfur (16)	S 35	S	3X10⁻⁷	2X10⁻³	9X10⁻⁹	6X10⁻⁶
		I	3X10⁻⁷	8X10⁻³	9X10⁻⁹	3X10⁻⁶
Tantalum (73)	Ta 182	S	4X10⁻⁹	1X10⁻⁴	1X10⁻⁹	4X10⁻⁶
		I	2X10⁻⁹	1X10⁻³	7X10⁻¹⁰	4X10⁻⁶
Technetium (43)	Tc 96m	S	8X10⁻⁶	4X10⁻²	3X10⁻⁷	1X10⁻⁵
		I	3X10⁻⁶	3X10⁻²	1X10⁻⁸	1X10⁻⁵
	Tc 96	S	6X10⁻⁷	3X10⁻³	2X10⁻⁸	1X10⁻⁶
		I	2X10⁻⁷	1X10⁻³	6X10⁻⁹	8X10⁻⁶
	Tc 97m	S	2X10⁻⁶	1X10⁻²	8X10⁻⁸	4X10⁻⁵
		I	2X10⁻⁷	8X10⁻³	8X10⁻⁹	2X10⁻⁶
	Tc 97	S	1X10⁻⁶	8X10⁻³	4X10⁻⁷	2X10⁻⁵
		I	3X10⁻⁷	2X10⁻³	1X10⁻⁸	8X10⁻⁶
	Tc 99m	S	4X10⁻⁶	2X10⁻²	1X10⁻⁷	6X10⁻⁵
		I	1X10⁻⁶	6X10⁻³	5X10⁻⁸	3X10⁻⁵
	Tc 99	S	2X10⁻⁶	1X10⁻²	7X10⁻⁸	3X10⁻⁵
		I	6X10⁻⁷	8X10⁻³	2X10⁻⁸	7X10⁻⁶
Tellurium (52)	Te 125m	S	4X10⁻⁷	8X10⁻³	1X10⁻⁸	2X10⁻⁵
		I	1X10⁻⁷	3X10⁻³	4X10⁻⁹	1X10⁻⁵
	Te 127m	S	1X10⁻⁷	2X10⁻³	5X10⁻⁹	6X10⁻⁶
		I	4X10⁻⁸	7X10⁻³	1X10⁻⁹	8X10⁻⁶
	Te 127	S	2X10⁻⁶	8X10⁻³	6X10⁻⁸	3X10⁻⁵
		I	9X10⁻⁷	5X10⁻³	3X10⁻⁸	2X10⁻⁵
	Te 129m	S	8X10⁻⁸	1X10⁻³	3X10⁻⁹	3X10⁻⁶
		I	[illegible]	5X10⁻⁴	1X10⁻⁹	2X10⁻⁶
	Te 129	S	5X10⁻⁶	2X10⁻²	2X10⁻⁷	6X10⁻⁵
		I	4X10⁻⁶	2X10⁻²	1X10⁻⁷	8X10⁻⁵
	Te 131m	S	4X10⁻⁷	2X10⁻³	1X10⁻⁸	6X10⁻⁶
		I	2X10⁻⁷	1X10⁻³	6X10⁻⁹	4X10⁻⁶
	Te 132	S	2X10⁻⁷	9X10⁻⁴	7X10⁻⁹	3X10⁻⁶
		I	1X10⁻⁷	6X10⁻⁴	4X10⁻⁹	2X10⁻⁶
Terbium (65)	Tb 160	S	1X10⁻⁷	1X10⁻³	3X10⁻⁹	4X10⁻⁶
		I	3X10⁻⁶	1X10⁻³	1X10⁻⁸	4X10⁻⁶
Thallium (81)	Tl 200	S	3X10⁻⁶	1X10⁻³	9X10⁻⁸	4X10⁻⁶
		I	1X10⁻⁶	7X10⁻³	4X10⁻⁸	2X10⁻⁵
	Tl 201	S	2X10⁻⁶	9X10⁻³	7X10⁻⁸	3X10⁻⁵
		I	9X10⁻⁷	8X10⁻³	3X10⁻⁸	2X10⁻⁵
	Tl 202	S	8X10⁻⁷	4X10⁻³	3X10⁻⁸	1X10⁻⁵
		I	2X10⁻⁷	2X10⁻³	8X10⁻⁹	7X10⁻⁶
	Tl 204	S	6X10⁻⁷	3X10⁻³	2X10⁻⁸	1X10⁻⁵
		I	3X10⁻⁷	2X10⁻³	9X10⁻¹⁰	6X10⁻⁶
Thorium (90)	Th 226	S	9X10⁻¹⁰	2X10⁻⁴	3X10⁻¹¹	7X10⁻⁶
		I	6X10⁻¹⁰	4X10⁻⁴	2X10⁻¹¹	10⁻⁵
	Th 230	S	2X10⁻¹⁰	8X10⁻⁴	8X10⁻¹⁰	2X10⁻⁵
		I	10⁻¹⁰	9X10⁻⁴	3X10⁻¹¹	3X10⁻⁵
	Th 232	S	3X10⁻¹⁰	8X10⁻⁴	10⁻¹²	2X10⁻⁵
		I	3X10⁻¹⁰	10⁻³	10⁻¹⁰	4X10⁻⁵
	Th natural	S	3X10⁻¹⁰	3X10⁻⁴	10⁻¹⁰	10⁻⁵
		I	3X10⁻¹⁰	3X10⁻⁴	10⁻¹⁰	10⁻⁵
	Th 234	S	6X10⁻⁸	4X10⁻⁴	2X10⁻⁹	2X10⁻⁵
		I	3X10⁻⁸	8X10⁻⁴	10⁻⁹	2X10⁻⁵
Thulium (69)	Tm 170	S	4X10⁻⁷	1X10⁻³	1X10⁻⁸	5X10⁻⁶
		I	3X10⁻⁷	1X10⁻³	1X10⁻⁸	5X10⁻⁶
	Tm 171	S	1X10⁻⁷	1X10⁻³	4X10⁻⁹	5X10⁻⁶
		I	2X10⁻⁷	1X10⁻³	8X10⁻⁹	4X10⁻⁶
Tin (50)	Sn 113	S	4X10⁻⁷	2X10⁻³	1X10⁻⁸	9X10⁻⁶
		I	3X10⁻⁷	2X10⁻³	2X10⁻⁸	8X10⁻⁶
	Sn 125	S	1X10⁻⁷	5X10⁻⁴	4X10⁻⁹	2X10⁻⁶
		I	8X10⁻⁸	8X10⁻⁴	3X10⁻⁹	2X10⁻⁵
Tungsten (Wolfram) (74)	W 181	S	2X10⁻⁶	1X10⁻³	8X10⁻⁸	4X10⁻⁵
		I	1X10⁻⁷	1X10⁻³	4X10⁻⁹	3X10⁻⁵
	W 185	S	8X10⁻⁷	4X10⁻³	3X10⁻⁸	1X10⁻⁵
		I	1X10⁻⁷	3X10⁻³	4X10⁻⁹	1X10⁻⁵
	W 187	S	4X10⁻⁷	2X10⁻³	2X10⁻⁸	7X10⁻⁶
		I	3X10⁻⁷	2X10⁻³	1X10⁻⁸	6X10⁻⁶
Uranium (92)	U 230	S	3X10⁻¹⁰	1X10⁻⁴	1X10⁻¹¹	8X10⁻⁶
		I	1X10⁻¹⁰	1X10⁻⁴	4X10⁻¹²	8X10⁻⁶
	U 232	S	1X10⁻¹⁰	8X10⁻⁴	3X10⁻¹¹	3X10⁻⁵
		I	3X10⁻¹¹	8X10⁻⁴	8X10⁻¹²	3X10⁻⁵
	U 233	S	6X10⁻¹⁰	9X10⁻⁴	2X10⁻¹¹	3X10⁻⁵
		I	1X10⁻¹⁰	9X10⁻⁴	4X10⁻¹²	3X10⁻⁵
	U 234	S	6X10⁻¹⁰	9X10⁻⁴	2X10⁻¹¹	3X10⁻⁵

TABLE B-1

APPENDIX B—Continued

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND—continued

[See Notes at end of appendix]

Element (atomic number)	Isotope [1]		Table I		Table II	
			Column 1 Air (μc/ml)	Column 2 Water (μc/ml)	Column 1 Air (μc/ml)	Column 2 Water (μc/ml)
	U 235	I	1×10^{-10}	6×10^{-4}	4×10^{-12}	3×10^{-6}
		S[2]	8×10^{-10}	8×10^{-4}	2×10^{-11}	3×10^{-6}
	U 236	I	1×10^{-10}	8×10^{-4}	4×10^{-12}	3×10^{-6}
		S	6×10^{-10}	1×10^{-3}	2×10^{-11}	3×10^{-6}
	U 238	I	1×10^{-10}	1×10^{-3}	4×10^{-12}	3×10^{-6}
		S[2]	7×10^{-11}	1×10^{-3}	3×10^{-12}	4×10^{-6}
	U 240	I	1×10^{-10}	1×10^{-3}	8×10^{-12}	4×10^{-6}
		S	2×10^{-7}	1×10^{-3}	6×10^{-9}	3×10^{-6}
	U-natural	I	2×10^{-7}	1×10^{-3}	6×10^{-9}	3×10^{-6}
		S[2]	7×10^{-11}	8×10^{-4}	3×10^{-12}	2×10^{-6}
Vanadium (23)	V 48	I	6×10^{-11}	8×10^{-4}	2×10^{-12}	2×10^{-6}
		S	2×10^{-7}	9×10^{-4}	6×10^{-9}	3×10^{-6}
Xenon (54)	Xe 131m	I	6×10^{-7}	8×10^{-4}	2×10^{-8}	3×10^{-6}
		Sub	2×10^{-6}	----------	4×10^{-7}	----------
	Xe 133	Sub	1×10^{-6}	----------	3×10^{-7}	----------
	Xe 133m	Sub	1×10^{-6}	----------	3×10^{-7}	----------
	Xe 135	Sub	4×10^{-6}	----------	1×10^{-7}	----------
Ytterbium (70)	Yb 175	S	7×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-6}
		I	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-6}
Yttrium (39)	Y 90	S	1×10^{-7}	6×10^{-4}	4×10^{-9}	2×10^{-6}
		I	1×10^{-7}	6×10^{-4}	3×10^{-9}	2×10^{-6}
	Y 90m	S	2×10^{-6}	1×10^{-3}	8×10^{-7}	3×10^{-6}
		I	2×10^{-6}	1×10^{-3}	6×10^{-7}	3×10^{-6}
	Y 91	S	4×10^{-8}	8×10^{-4}	1×10^{-9}	3×10^{-6}
		I	3×10^{-8}	8×10^{-4}	1×10^{-9}	3×10^{-6}
	Y 92	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-6}
		I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-6}
	Y 93	S	2×10^{-7}	8×10^{-4}	6×10^{-9}	3×10^{-6}
		I	1×10^{-7}	8×10^{-4}	5×10^{-9}	3×10^{-6}
Zinc (30)	Zn 65	S	1×10^{-7}	3×10^{-3}	4×10^{-9}	1×10^{-6}
		I	6×10^{-8}	6×10^{-3}	2×10^{-9}	2×10^{-6}
	Zn 69m	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	7×10^{-6}
		I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-6}
	Zn 69	S	7×10^{-6}	5×10^{-3}	2×10^{-7}	2×10^{-5}
		I	9×10^{-6}	5×10^{-3}	3×10^{-7}	2×10^{-5}
Zirconium (40)	Zr 93	S	1×10^{-7}	2×10^{-2}	4×10^{-9}	6×10^{-5}
		I	3×10^{-7}	2×10^{-2}	1×10^{-8}	8×10^{-5}
	Zr 95	S	1×10^{-7}	2×10^{-3}	4×10^{-9}	6×10^{-6}
		I	3×10^{-8}	2×10^{-3}	1×10^{-9}	6×10^{-6}
	Zr 97	S	1×10^{-7}	8×10^{-4}	4×10^{-9}	2×10^{-6}
		I	9×10^{-8}	8×10^{-4}	3×10^{-9}	2×10^{-6}
Any single radionuclide not listed above with decay mode other than alpha emission or spontaneous fission and with radioactive half-life less than 2 hours.		Sub	1×10^{-6}	----------	3×10^{-8}	----------
Any single radionuclide not listed above with decay mode other than alpha emission or spontaneous fission and with radioactive half-life greater than 2 hours.	----------		3×10^{-8}	9×10^{-3}	1×10^{-10}	3×10^{-6}
Any single radionuclide not listed above, which decays by alpha emission or spontaneous fission.	----------		8×10^{-12}	4×10^{-7}	2×10^{-14}	3×10^{-6}

[1] Soluble (S); Insoluble (I).

[2] "Sub" means that values given are for submersion in a semi-spherical infinite cloud of airborne material.

[3] These radon concentrations are appropriate for protection from radon-222 combined with its short-lived daughters. Alternatively, the value in Table I may be replaced by one-third (⅓) "working level." (A "working level" is defined as any combination of short-lived radon-222 daughters, polonium-218, lead-214, bismuth-214 and polonium-214, in one liter of air, without regard to the degree of equilibrium, that will result in the ultimate emission of 1.3×10^5 MeV of alpha particle energy.) The Table II value may be replaced by one-thirtieth (1/30) of a "working level." The limit on radon-222 concentrations in restricted areas may be based on an annual average.

[4] For soluble mixtures of U-238, U-234 and U-235 in air chemical toxicity may be the limiting factor. If the percent by weight (enrichment) of U-235 is less than 5, the concentration value for a 40-hour workweek, Table I, is 0.2 milligrams uranium per cubic meter of air average. For any enrichment, the product of the average concentration and time of exposure during a 40-hour workweek shall not exceed 8×10^{-9} SA μCi-hr/ml, where SA is the specific activity of the uranium inhaled. The concentration value for Table II is 0.007 milligrams uranium per cubic meter of air. The specific activity for natural uranium is 6.77×10^{-7} curies per gram U. The specific activity for other mixtures of U-238, U-235 and U-234, if not known, shall be:

$SA = 3.6\times10^{-7}$ curies/gram U U-depleted E≥0.72

$SA = (0.4+0.38\,E+0.0034\,E^2)\,10^{-6}$

where E is the percentage by weight of U-235, expressed as percent.

[39 FR 23990, June 28, 1974]

NOTE: In any case where there is a mixture in air or water of more than one radionuclide, the limiting values for purposes of this Appendix should be determined as follows:

1. If the identity and concentration of each radionuclide in the mixture are known, the limiting values should be derived as follows: Determine, for each radionuclide in the mixture, the ratio between the quantity present in the mixture and the limit otherwise established in Appendix B for the specific radionuclide when not in a mixture. The sum of such ratios for all the radionuclides in the mixture may not exceed "1" (i.e., "unity").

EXAMPLE: If radionuclides A, B, and C are present in concentrations C_A, C_B, and C_C, and if the applicable MPC's, are MPC_A, and MPC_B, and MPC_C respectively, then the concentrations shall be limited so that the following relationship exists:

$$\frac{C_A}{MPC_A}+\frac{C_B}{MPC_B}+\frac{C_C}{MPC_C}\leq 1$$

2. If either the identity or the concentration of any radionuclide in the mixture is not known, the limiting values for purposes of Appendix B shall be:

a. For purposes of Table I, Col. 1—4×10^{-12}
b. For purposes of Table I, Col. 2—4×10^{-7}
c. For purposes of Table II, Col. 1—2×10^{-14}
d. For purposes of Table II, Col. 2—3×10^{-6}

3. If any of the conditions specified below are met, the corresponding values specified below may be used in lieu of those specified in paragraph 2 above.

a. If the identity of each radionuclide in the mixture is known but the concentration of one or more of the radionuclides in the mixture is not known the concentration limit for the mixture is the limit specified in Appendix "B" for the radionuclide in the mixture having the lowest concentration limit; or

b. If the identity of each radionuclide in the mixture is not known, but it is known that certain radionuclides specified in Appendix "B" are not present, the concentration limit for the mixture is the lowest concentration limit specified in Appendix "B" for any radionuclide which is not known to be absent from the mixture; or

APPENDIX B—Continued
CONCENTRATION IN AIR AND WATER ABOVE NATURAL BACKGROUND—continued
[See notes at end of appendix]

Element (atomic number) and isotope	Table I		Table II	
	Col 1 Air (μCi/ml)	Col 2 Water (μCi/ml)	Col 1 Air (μCi/ml)	Col 2 Water (μCi/ml)
If it is known that Sr 90, I 125, I 126, I 129, I 131 (I 133 table II only), Pb 210, Po 210, Ac 211, Ra 223, Ra 224, Ra 225, Ac 227, Ra 228, Th 230, Pa 231, Th 232, Th-nat, Cm 248, Cf 254, and Fm 256 are not present	.....	9×10^{-9}	.....	3×10^{-7}
If it is known that Sr 90, I 125, I 126, I 129, I 131, I 133 (table II only), Pb 210, Po 210, Ra 223, Ra 226, Ra 228, Pa 231, Th-nat, Cm 248, Cf 254, and Fm 256 are not present	.....	6×10^{-8}	.....	2×10^{-6}
If it is known that Sr 90, I 129 (I 125, I 126, I 131, table II only), Pb 210, Ra 226, Ra 228, Cm 248, and Cf 254 are not present	.....	2×10^{-8}	.....	6×10^{-7}
If it is known that (I 129 table II only), Ra 226, and Ra 228 are not present	.....	3×10^{-9}	.....	1×10^{-7}
If it is known that alpha-emitters and Sr 90, I 125, Pb 210, Ac 227, Ra 228, Pa 230, Pu 241, and Bk 249 are not present	3×10^{-9}	.....	1×10^{-10}	.....
If it is known that alpha-emitters and Pb 210, Ac 227, Ra 226, and Pu 241 are not present	3×10^{-10}	.....	1×10^{-11}	.....
If it is known that alpha-emitters and Ac 227 are not present	3×10^{-11}	.....	1×10^{-12}	.....
If it is known that Ac 227, Th 230, Pa 231, Pu 238, Pu 239, Pu 240, Pu 242, Pu 244, Cm 248, Cf 249, and Cf 251 are not present	3×10^{-12}	.....	1×10^{-13}	.....

4. If a mixture of radionuclides consists of uranium and its daughters in ore dust prior to chemical separation of the uranium from the ore, the values specified below may be used for uranium and its daughters through radium-228, instead of those from paragraphs 1, 2, or 3 above:

a. For purposes of Table I, Col 1—1×10^{-10} μCi/ml gross alpha activity, or 5×10^{-11} μCi/ml natural uranium, or 75 micrograms per cubic meter of air natural uranium.

b. For purposes of Table II, Col. 1—3×10^{-12} μCi/ml gross alpha activity, 2×10^{-12} μCi/ml natural uranium, or 3 micrograms per cubic meter of air natural uranium.

5. For purposes of this note, a radionuclide may be considered as not present in a mixture if (a) the ratio of the concentration of that radionuclide in the mixture (C_a) to the concentration limit for that radionuclide specified in Table II of Appendix "B" (MPC_a) does not exceed 1/10, (i.e. $C_a/MPC_a \leq 1/10$) and (b) the sum of such ratios for all the radionuclides considered as not present in the mixture does not exceed ¼, i.e.

$$(C_a/MPC_a + C_b/MPC_b \ldots) \leq 1/4$$

APPENDIX C

Material	Microcuries	Material	Microcuries	Material	Microcuries
Americium-241	01	Erbium-169	100	Krypton-87	1
Antimony-122	100	Erbium-171	100	Lanthanum-140	1
Antimony-124	10	Europium-152 9.2 h	100	Lutetium-177	10
Antimony-125	10	Europium-152 13 yr	1	Manganese-52	1
Arsenic-73	100	Europium-154	1	Manganese-54	1
Arsenic-74	10	Europium-155	10	Manganese-56	1
Arsenic-76	10	Fluorine-18	1,000	Mercury-197m	10
Arsenic-77	100	Gadolinium-153	10	Mercury-197	10
Barium-131	10	Gadolinium-159	100	Mercury-203	1(
Barium-133	10	Gallium-72	10	Molybdenum-99	10
Barium-140	10	Germanium-71	100	Neodymium-147	10
Bismuth-210	1	Gold-198	100	Neodymium-149	10(
Bromine-82	10	Gold-199	100	Nickel-59	10(
Cadmium-109	10	Hafnium-181	10	Nickel-63	1(
Cadmium-115m	10	Holmium-166	100	Nickel-65	10
Cadmium-115	100	Hydrogen-3	1,000	Niobium-93m	1(
Calcium-45	10	Indium-113m	100	Niobium-95	1(
Calcium-47	10	Indium-114m	10	Niobium-97	1(
Carbon-14	100	Indium-115m	100	Osmium-185	1(
Cerium-141	100	Indium-115	10	Osmium-191m	10(
Cerium-143	100	Iodine-125	1	Osmium-191	10(
Cerium-144	1	Iodine-126	1	Osmium-193	10(
Cesium-131	1,000	Iodine-129	0 1	Palladium-103	10(
Cesium-134m	100	Iodine-131	1	Palladium-109	10(
Cesium-134	1	Iodine-132	10	Phosphorus-32	1(
Cesium-135	10	Iodine-133	1	Platinum-191	10(
Cesium-136	10	Iodine-134	10	Platinum-193m	10(
Cesium-137	10	Iodine-135	10	Platinum-193	10(
Chlorine-36	10	Iridium-182	10	Platinum-197m	10(
Chlorine-38	10	Iridium-194	100	Platinum-197	10(
Chromium-51	1,000	Iron-55	100	Plutonium-239	0 1
Cobalt-58m	10	Iron-59	10	Polonium-210	0 1
Cobalt-58	10	Krypton-85	100	Potassium-42	10
Cobalt-60	1	Krypton-87	10	Praseodymium-142	10(
Copper-64	100	Lanthanum-140	10	Praseodymium-143	10(
Dysprosium-165	10	Lutetium-177	100	Promethium-147	10
Dysprosium-166	100	Manganese-52	10	Promethium-149	10